Tappi

PUBLISHED BY THE TECHNICAL ASSOCIATION OF THE PULP AND PAPER INDUSTRY

AUGUST 1949

An example of Penicillium. Magnification 36x

Are you interested in reducing machine "down" time?

Machine "breaks" in pulp and paper mills are often caused by uncontrolled bacterial attack through many stages of production. Nowhere is the control of mold and bacteria more important than in the pulp and paper industry. Now, Dowicides—Dow's germicides and fungicides—can give you protection against such costly losses in machine down-time and defective material.

Dowicides serve as protection against mildew and rot in practically all of the pulp and paper manufacturing processes—from wood preparing operations through the final use of finished products. Sap stain and dry rot of pulp wood, fungi on lap stock, bacterial attack on machine felt, deterioration of sizes and adhesives, and slime growths—all may be effectively controlled with the proper Dowicide.

Investigate Dowicides now. Find out how these effective germicides and fungicides can help cut material losses and machine down time. Complete laboratory facilities are maintained by Dow to help you solve your bacterial and mold problems. Contact your nearest Dow office or write direct to Midland

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Known to paper makers the world over, the big modern plant of Beloit Iron Works at Beloit, Wisconsin,

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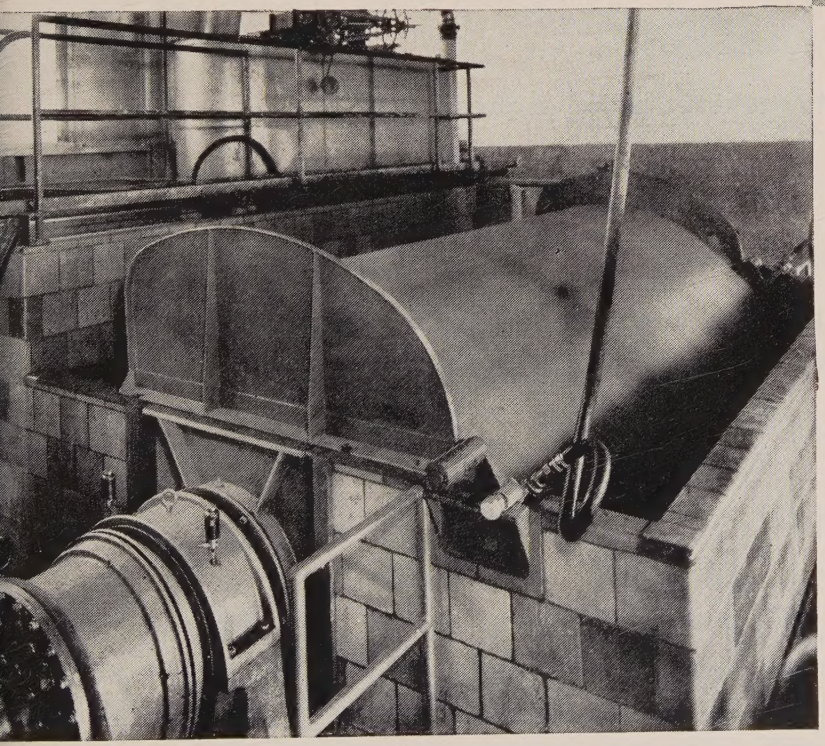
OLIVER Rubber Covered SAVEALL

ile combines exceptionally low maintenance, non-contaminat-
ng contact surfaces and great durability. Life is mill-life. Physi-
al damage is easily repaired. No exterior painting is required.
aving furnished all types of vats for Savealls over a period of
any years we know their relative values. We recommend
ILE when conditions call for corrosion prevention and
ermit permanency of installation. Tile is used at the Ta-
oma, Washington, mill of the St. Regis Paper Company,
here this Saveall is installed.

he Oliver Saveall of today represents the experience of
ore than twenty-five years of service to the paper indus-
y during which time several hundred of these highly
fficient fibre recovery units have been installed, including
any during the past year or two. With today's units, we
an offer a choice of three distinctly different dischargers,
us assuring complete and clean discharge regardless
f the nature of stock handled. Where anti-corrosion is
nperative, we can provide rubber protected surfaces
ith stainless steel wire decks and stainless outlet pipes.
r you can get a combination of wood and cast iron.

short, we can provide just the Saveall you need to eco-
omically and properly recover the values in your mill.

note the TILE vat!



. . . A Few OLIVER SAVEALL Features

- Recent installations are for handling: kraft, sulphite, old paper, tissue furnishes
- Handles wet breaks as well as white water without separate system
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- Has shown maintenance and labor costs as low as 3½ cents per ton

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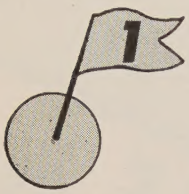
5 MONEY SAVING ADVANTAGES of the CONKEY INTEGRAL EVAPORATOR



Erection time generally *one quarter* that required for other types.

Vapor body, heating element, entrainment separator and flash chamber constructed in one common shell which is set into place in one operation.

As much as 30% reduction in floor space.

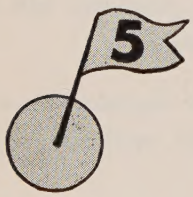
No external entrainment separators and flash chambers.

Negligible pressure drop.

Due to streamlining of design and integration of construction.

Increased evaporator capacity.

Due to great reduction of pressure drop.



Minimum maintenance.

Design has eliminated many flanged joints and a space exists between shell and outer row of tubes wide enough for a man to walk through and inspect tubes.

OTHER GENERAL AMERICAN EQUIPMENT		
Digestors	Filters	Kilns
Blow Tanks	Evaporators	Bins
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AUGUST 1949

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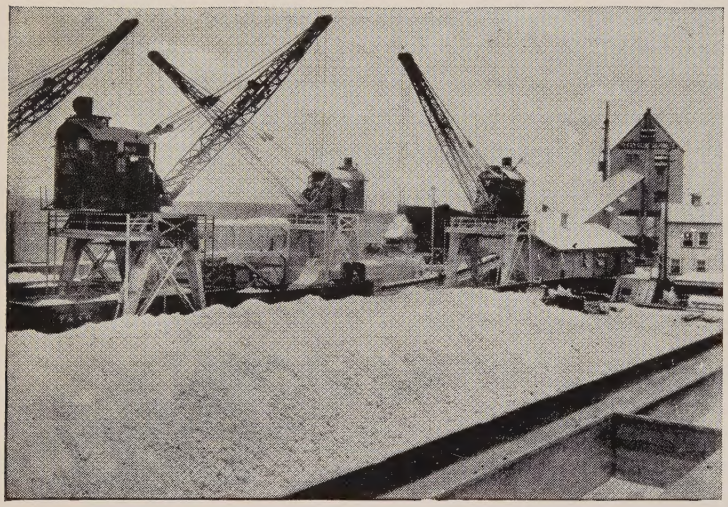
SULPHUR

*Interesting Facts Concerning This Basic Raw Material from the Gulf Coast Region

*LOADING



Sulphur intended for vessel shipment is brought to Galveston by rail from the mines at Newgulf. It is transferred directly from cars or from storage bins to the vessel.

The loading plant consists of two parallel storage bins spaced far enough apart to allow room for railroad tracks, tracks for the hoppers and cranes, and an endless conveyor belt. The belt along the center line between the bins is straddled by four cranes and their movable hoppers.

The cranes pick up the sulphur from the bins or cars and discharge into the hoppers, which automatically feed the belt. It is weighed while on this moving belt. After weighing it is discharged onto a smaller belt which in turn discharges through a cylindrical telescopic spout directly into the vessel's hold.

Be Sure To Go To The Portland TAPPI Meeting

Loading operations at one of the huge vats of Sulphur at our Newgulf, Texas mine. Such mountains of Sulphur are constantly being built at our mines, from which shipments are continually made.

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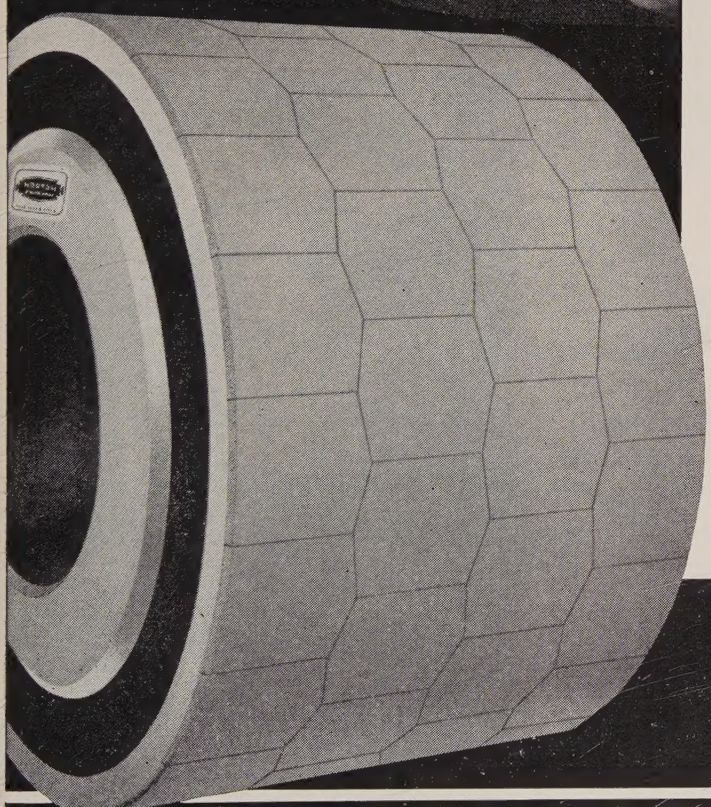
Mines: Newgulf and Moss Bluff, Texas

Real Engineering Service

To produce the type of pulp that you need from your type of wood, I recommend a 37C546-M7V stone. Also I suggest . . .



YES, that's what you get from your Norton pulpstone engineer — *really helpful engineering service*. He will study your particular pulp requirements, your type of wood and your equipment. From that he'll recommend a stone of just the right kind of abrasive, grit size, hardness and structure to meet your mill conditions. You'll also find that his years of experience in the pulp and paper industry will enable him to give you many helpful suggestions for producing pulp better or more economically. And he will be glad to assist with any other grinding wheel problems which you may have.

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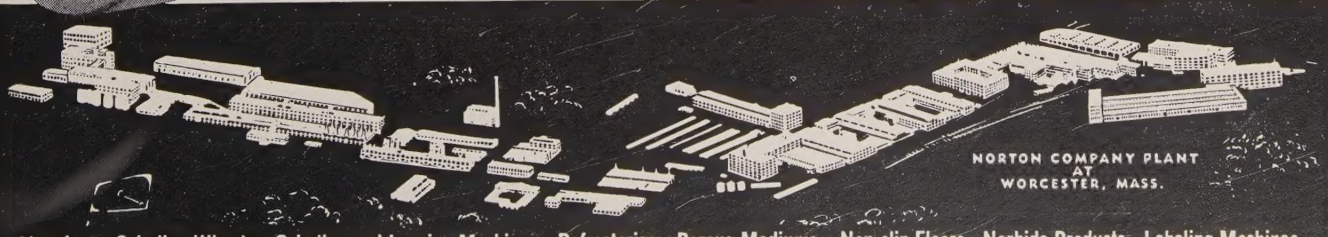

Abrasives - Grinding Wheels - Grinding and Lapping Machines - Refractories - Porous Mediums - Non-slip Floors - Norbide Products - Labeling Machines

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SOLVAY Technical Service Men include specialists in the paper industry. They know your needs and your problems through long years of experience in the field. Call on them.

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SOLVAY fine quality shows up in efficient, economical results in your plant. SOLVAY products are immediately available in unlimited supply from local stocks, and from SOLVAY plants and warehouses coast-to-coast.

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SOLVAY has served the paper industry for over half a century. This experience, plus continuing research in paper problems, has made SOLVAY a dependable source for chemicals vital to paper production.

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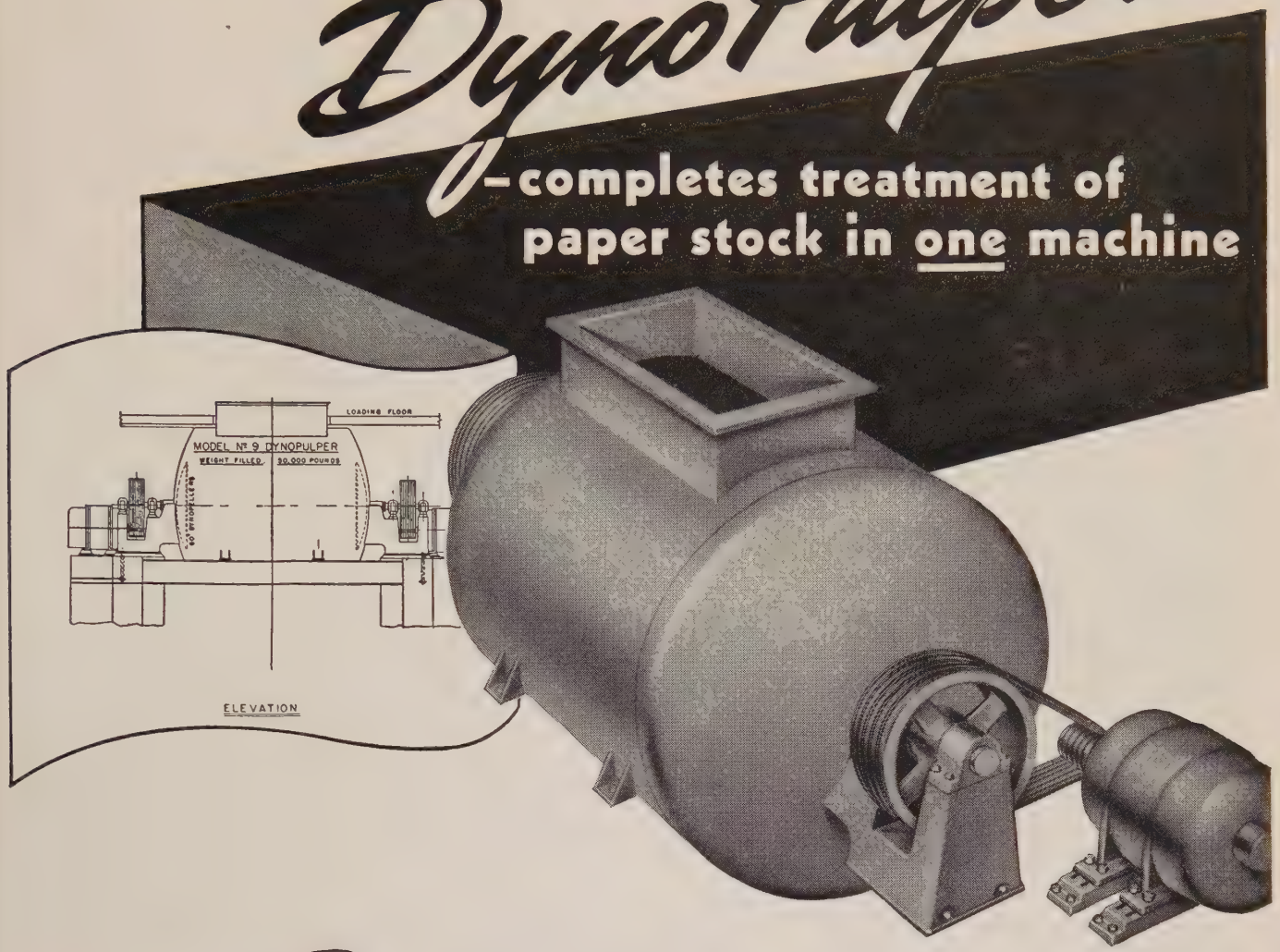
Here's the new DynoPulper

—completes treatment of paper stock in one machine



The DynoPeller

is the heart of all DynoMachines. Its concave face is lined with rough, hard carbide particles. As the DynoPeller rotates it causes a suction at its center that pulls the stock towards it. Centrifugal force then causes the stock to flow rapidly over the rough carbide particles. This effective dynomizing action completely disintegrates the stock . . . separating each fibre from its neighbor while maintaining its original length.

The DynoPulper

is a highly efficient machine for disintegrating pulp, waste paper or any type of stock. The stock is charged all at one time into the top of the horizontal circular vat. It is vigorously dynomized by two opposing DynoPellers—as described at the left. The fibres are quickly and completely separated . . . at surprisingly low cost.

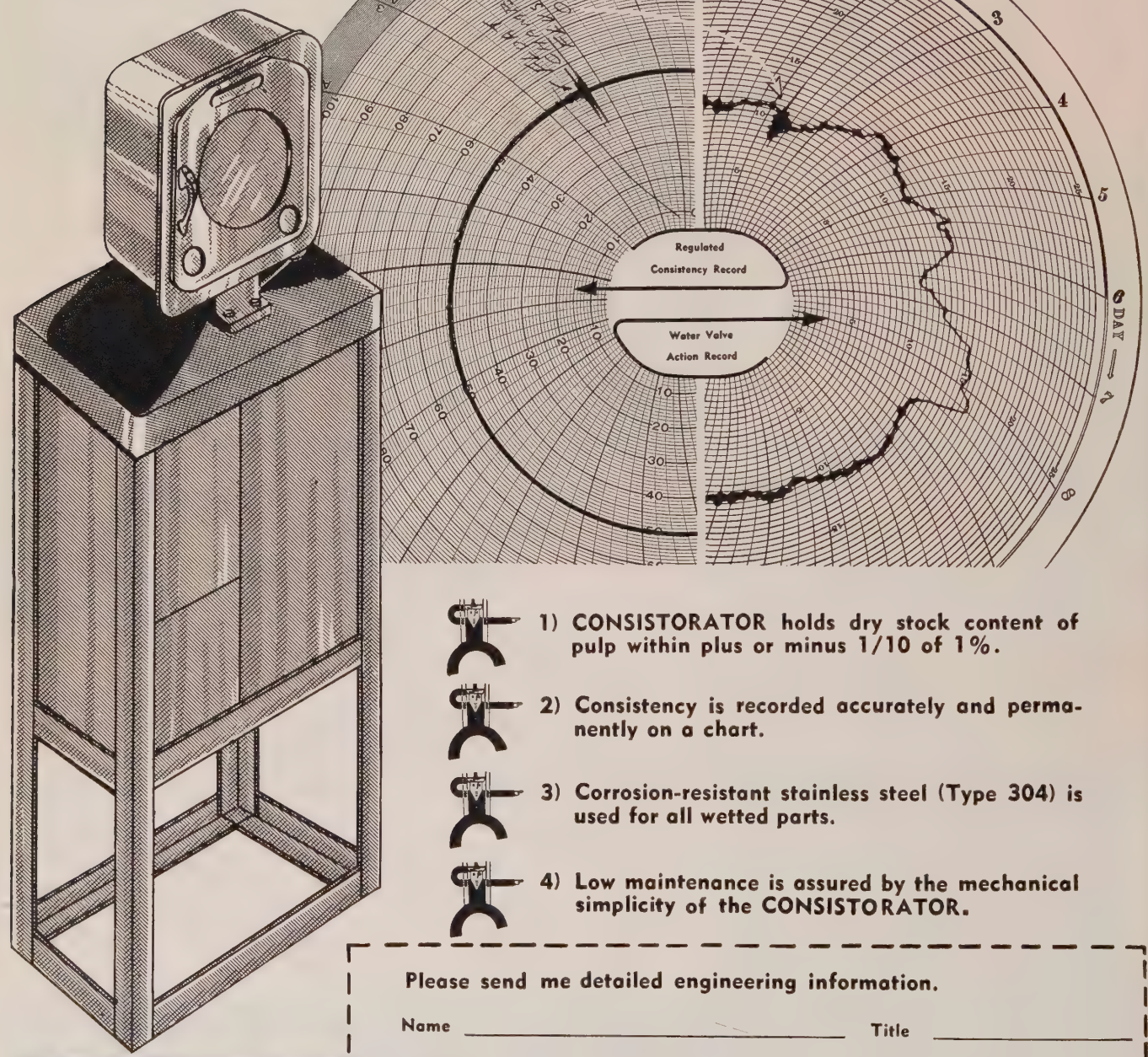
The DynoPulper is used for either batch or continuous operation. Also available in laboratory sizes. Write for additional information.

RBR-3

RICE BARTON Research Corporation

WORCESTER 1, MASS.

STOCK CONSISTENCY CONTROLLED AND RECORDED WITH THE *New*— F & P CONSISTORATOR



1) CONSISTORATOR holds dry stock content of pulp within plus or minus 1/10 of 1%.

2) Consistency is recorded accurately and permanently on a chart.

3) Corrosion-resistant stainless steel (Type 304) is used for all wetted parts.

4) Low maintenance is assured by the mechanical simplicity of the CONSISTORATOR.

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PROCESS CONTROL INSTRUMENTS

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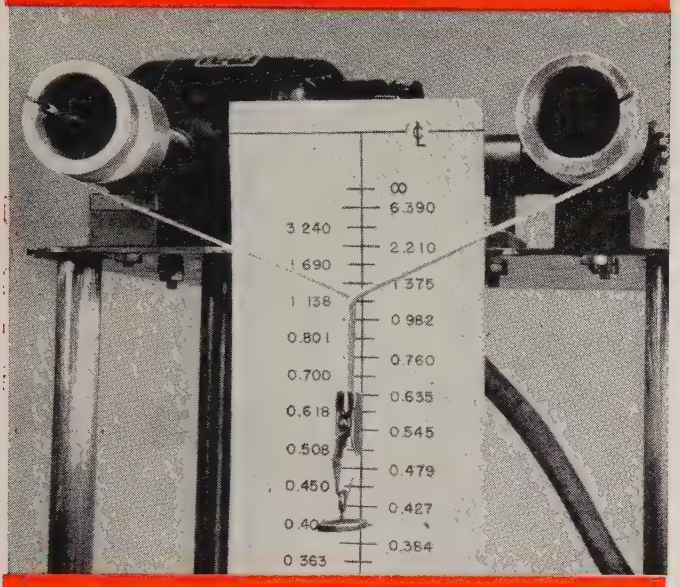
NEW MAGNOWAX IS STRONGER, TOUGHER...

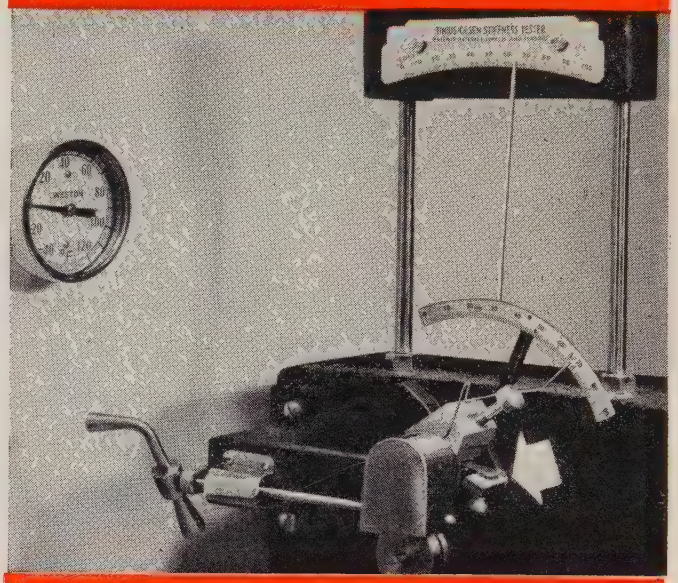
for Laminating!



Here's how laminating strength is tested on a new device developed by Socony-Vacuum.

MORE FLEXIBLE

at low temperatures for frozen food packaging and storage!



Here's how flexibility is tested at controlled low temperatures.

Latest Socony-Vacuum Microcrystalline Wax Sets New Standards

Here . . . available right now for your use . . . is a great *new* microcrystalline wax . . . *Socony-Vacuum Magnowax* . . . perfected by the company that first brought you all of the advantages of microcrystalline waxes.

S/V Magnowax is far superior to other microcrystalline waxes, exceeding even Socony-Vacuum's previous products which set the standards in this field.

S/V Magnowax is tougher, more adhesive . . . it strengthens the seal, gives perfect lamination.

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High or Low! — Hot or Cold! — it makes no difference. *S/V Magnowax* stays *put!* See your Socony-Vacuum Representative for details.

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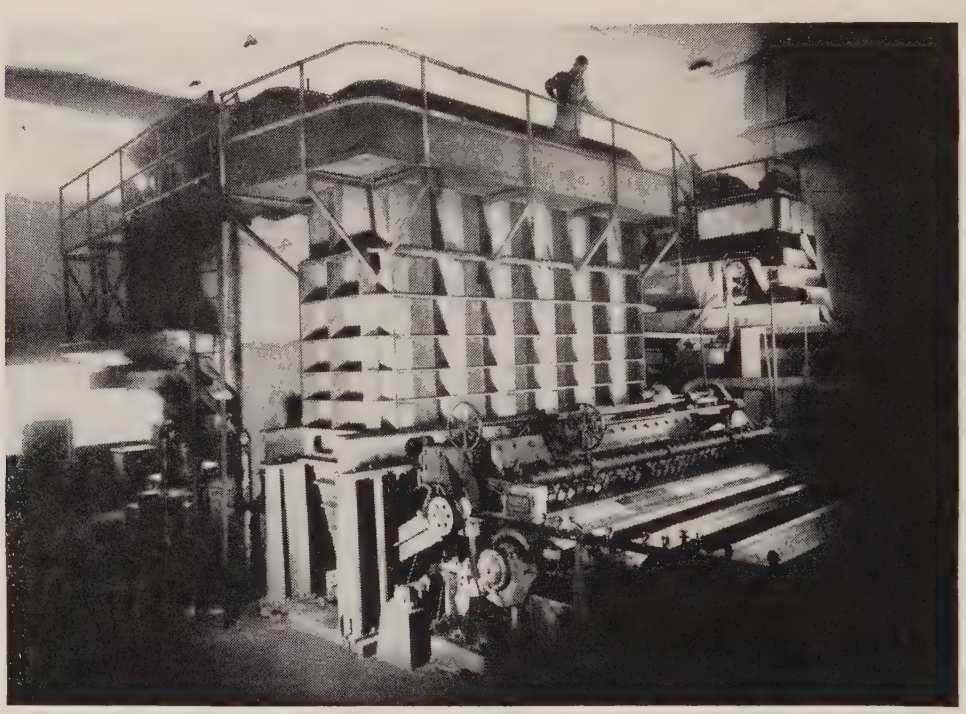
Socony-Vacuum Process Products SOCONY-VACUUM **PROCESS PRODUCTS**

Built by

LUKENWELD

FOR SCOTT PAPER COMPANY



This paper machine headbox, built of Lukens Stainless-Clad Steel, replaced another type of structure. It regulates the flow of pulp to a paper-making machine, according to the type of paper being made.

Flow lines needed in this headbox to distribute pulp properly for top-quality paper production were developed by Scott Paper Company. Then they asked Lukenweld, "Can you build us a headbox to these requirements?"

Lukens Stainless-Clad Steel, Type 304, was employed, providing *solid* corrosion-resistant metal protection with *clad* steel economy.

That's how Lukenweld likes to work —applying our knowledge of plate-product engineering to another man's problems. Planning the structure to meet his specifications, selecting materials for most economical performance, building it; Lukenweld service is that complete.

Have you a problem we can help solve? Write Lukenweld, Division of Lukens Steel Company, 501 Lukens Building, Coatesville, Pennsylvania.

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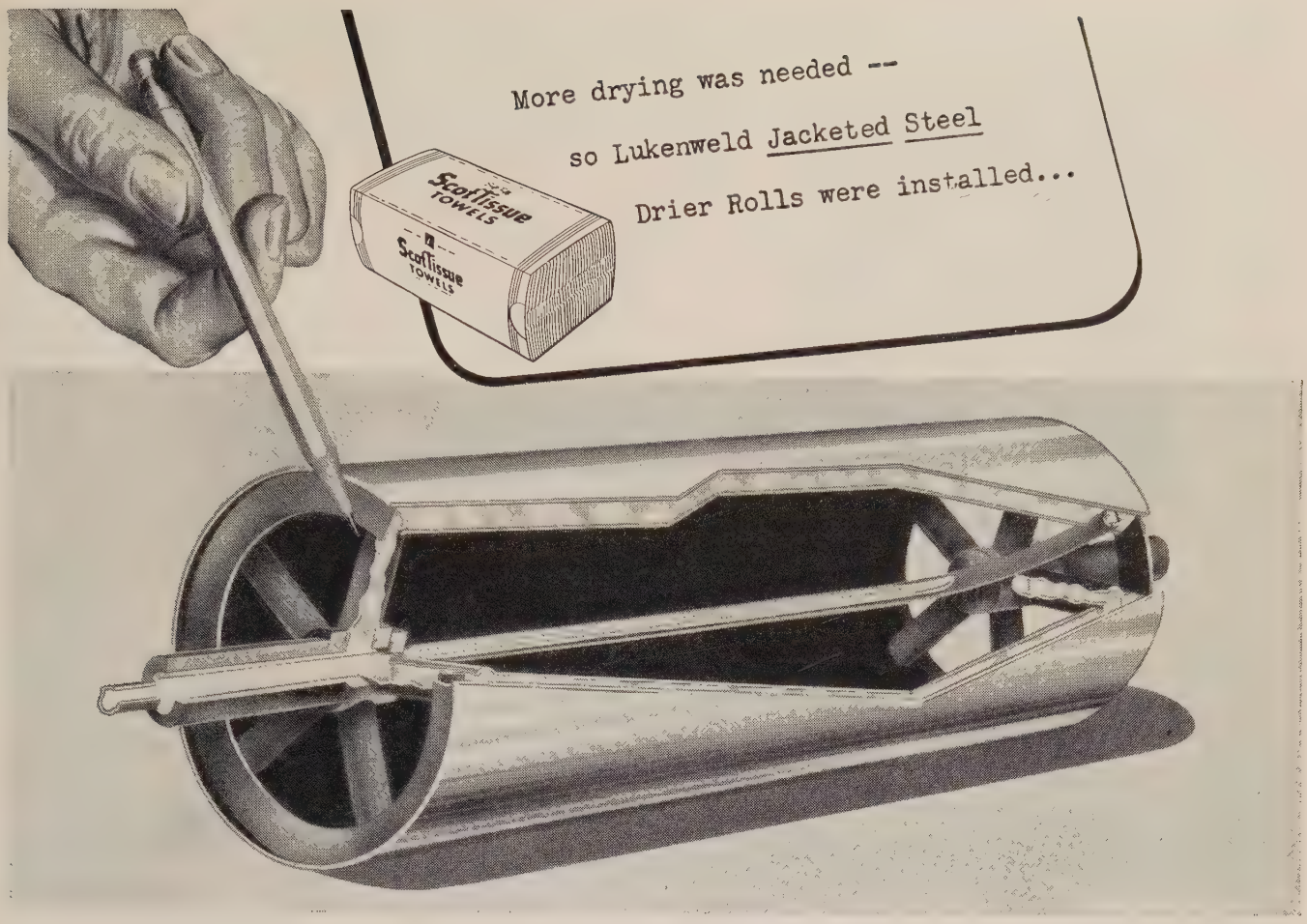


Towel machine at SCOTT PAPER COMPANY reaches an acceptable production rate faster...*with safety*

When engineers at Scott Paper Company required extra drying capacity on a paper towel machine, they installed a number of Lukenweld Jacketed Steel Drier Rolls in the machine.

The needed drying was thus supplied, with an extra dividend of safety due to the welded steel construction of these rolls. They contributed to the successful start-up of the machine and the early attainment of an acceptable rate of production.

Lukenweld Drier Rolls owe their performance to these factors: Their jacketed design gives positive scavenging of entrapped air, film and condensate from steam passages, assuring high efficiency. Made of steel plate, wall sections can be thinner with safety, giving rapid heat transfer, with even and constant surface temperatures.

Whatever your roll-drying problems, Lukenweld can serve you. Our engineers will help select the rolls you need, and even design and build the complete machine. Pressures up to 350 psi and higher can be safely employed.

Bulletin 358 tells you more about Lukenweld Jacketed Steel Drier Rolls. For a copy, and for help on your machinery requirements write Lukenweld, Division of Lukens Steel Company, 501 Lukens Building, Coatesville, Pa.

OF DRIER ROLLS AND DRYING MACHINERY

LUKENS
LUKENWELD DIVISION

The PRESIDENT'S PAGE

Albert E. Bachmann

TAPPI Fall Meeting

Since its organization in 1915 TAPPI has held each year, except as restricted by wartime travel limitations, at least two national meetings. The primary purpose of these meetings has been to provide a means for the executives, production men, and technical men to meet each other and to discuss problems of mutual interest on the many phases of operation, testing methods, and research that they possess in common.

The specific benefits available to the men and their mills by attendance at these meetings are in many cases very practical. They bring back with them many new ideas concerning equipment, process, and control methods, which they can investigate for practical feasibility of incorporating, with value, into their own procedures. They receive corroboration of their own ideas, independently arrived at by others with common problems, to confirm their judgments on impending decisions on complex equipment and process problems. The mutual exchange of experiences arising from time-consuming effort and often considerable expense applied to differing problems, saves time and cost for all participants. Exchange of mutual experiences also often brings to light some of the equipment and raw material rigidities, which often preclude the completely successful solution of their specific problems by individual mills. The TAPPI meetings also benefit the mill men by concentrating in one place and at one time the comparative descriptions, advices, and new developments on equipment and raw materials of our supplier members.

Heretofore, these benefits have been realized at the TAPPI meetings, not only through the medium of large general meetings with discussions but also to a considerable extent on an informal basis, by individual or small group contacts. In an effort to formalize to a greater degree the informal meetings of the past and make them more generally available and hence more valuable, TAPPI, of late years, has introduced into its sessions round-table discussions and the specialized topical type meeting.

For many years it was the practice of the Technical Association to hold a general fall meeting in the vicinity of important paper mill centers in order to bring TAPPI to a large local audience and to afford an opportunity for mill visits in connection with the meetings. With the growth of TAPPI to more than 4000 members and the trend toward specialization of its meetings of recent years TAPPI has, of necessity, run several topical-type fall meetings for its specialized groups. Among these have been meetings devoted exclusively to such subjects as Alkaline Pulping, Fundamental Research, Engineering, Testing, Coating, Groundwood, and Straw Pulping.

This fall, however, TAPPI will once again, for the first time in 9 years, hold a general fall meeting on the West Coast at the invitation of our Pacific Coast Section. This National Meeting will be held in Portland, Ore., September 11–15. The committee has arranged one of the strongest technical programs in years. Included in the program are specific attractions for all TAPPI groups. The committee has arranged for a rare combination of broad and technical educational values enhanced by forest and mill visits of unusual character, as well as unique sight-seeing and entertainment features of background values.

Among the many features of interest to pulp men are a symposium on eastern, southern, and western pulpwoods built around The Institute of Paper Chemistry Staff, papers and a discussion centering around the new magnesia and ammonia base sulphite developments. A strong program of the new developments in kraft pulping is also being arranged.

The engineering program centers around a discussion of paper mill design; the fundamental research program will revolve around lignin studies and waste sulphite liquor; the papermaking program will revolve around the vital theme of quality control, a subject of paramount importance at this time.

Included also, as special features, are after-luncheon talks by Harold S. Foley, President of the Powell River Company, and Alexander R. Heron, Vice-President of the Crown Zellerbach Corp. Mr. Foley is the present chairman of the Canadian Paper and Pulp Association. Mr. Heron is the author of a series of books "Toward Understanding in Industry," among which is his widely acclaimed "Why Men Work."

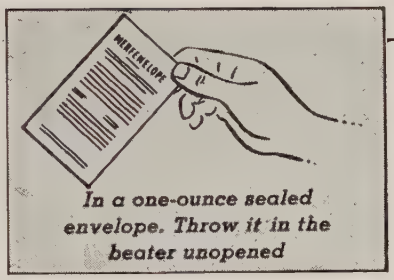
In the general sessions among other features will be talks on the Economic Status of the Industry, by E. W. Tinker, and the Educational Status, by John Strange of the Institute of Paper Chemistry.

In addition to this strong technical program a woods visit to the Weyerhaeuser limits and mill visits to the Crown Zellerbach mills at Camas and West Linn and the Weyerhaeuser sulphite and kraft mills at Longview are added attractions of the meeting.

(continued on page 16 A)

Merfenelopes

FOR SLIME CONTROL



In a one-ounce sealed envelope. Throw it in the beater unopened

Cleans Pipes
Kills Bacteria
Reduces Washups
Fewer Slime Rejects

R. T. VANDERBILT CO., INC.

230 Park Avenue, New York City

The DRAPER Felt
DRAPER BROTHERS COMPANY
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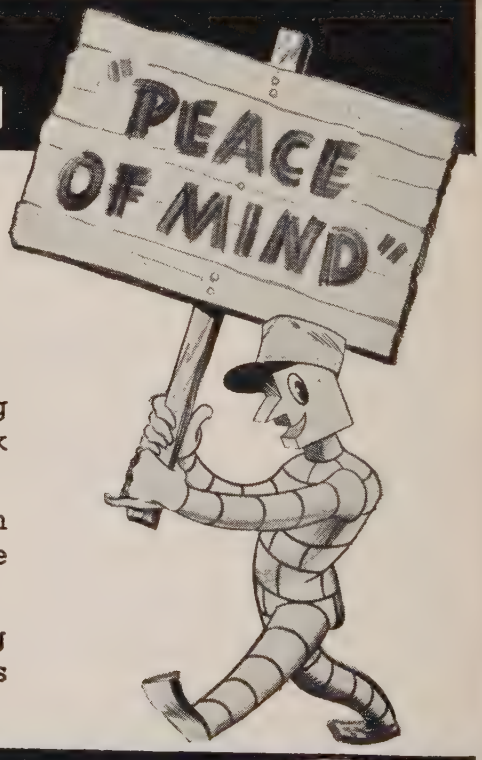
The west coast woods operations are decidedly unique. Visitors from the east will be greatly impressed and stimulated by the ingenuity of the mechanical handling of their large trees. The Crown Zellerbach organization is one of the most progressive in adaptations of modern industrial methods in the country Their mill at Camas with 13 paper machines is one of the world's largest Fourdrinier specialty mills, making many different grades of paper. At the Weyerhaeuser mill at Longview the latest developments in sulphate and sulphite pulping, including the new magnesia base process, will be seen.

The TAPPI Pacific Section, our host, is one of our strongest and most progressive sections, which has instituted many instructive and stimulating innovations in its meetings. Its national meetings have always set a very high standard of education and entertainment. The western mills in the past have contributed generously in subject material and expense in sending men east to contribute much of value to our meetings.

In order to make this meeting truly successful it is important to our Pacific hosts and to TAPPI to have a truly representative attendance of executives and specialists from the other TAPPI sections to complement their efforts. Such an opportunity to gain so much experience of value both to the individual and their mills occurs very rarely. We feel sure that the expenditure of time and money involved will be more than justified by these unusual values. We sincerely hope that all mills east of the Rockies will send at least one man to represent them at this outstanding program of events sponsored by our Pacific Section.

A STEBBINS LUMP SUM CONTRACT IS AN INVESTMENT IN



Whether the contract covers one chest or tank lining, or all the corrosion or alkali resistant linings for the entire mill, it is Stebbins responsibility to provide a dependable and satisfactory job that assures continuous operation.

- Sixty-five years experience in designing, installing and servicing linings in pulp and paper mills is back of this contract.
- Thousands of successful installations located on this continent and abroad provide tangible evidence of reliability.
- Think twice before investing in linings—the wrong one can prove very costly—be safe, specify Stebbins —and have no regrets.

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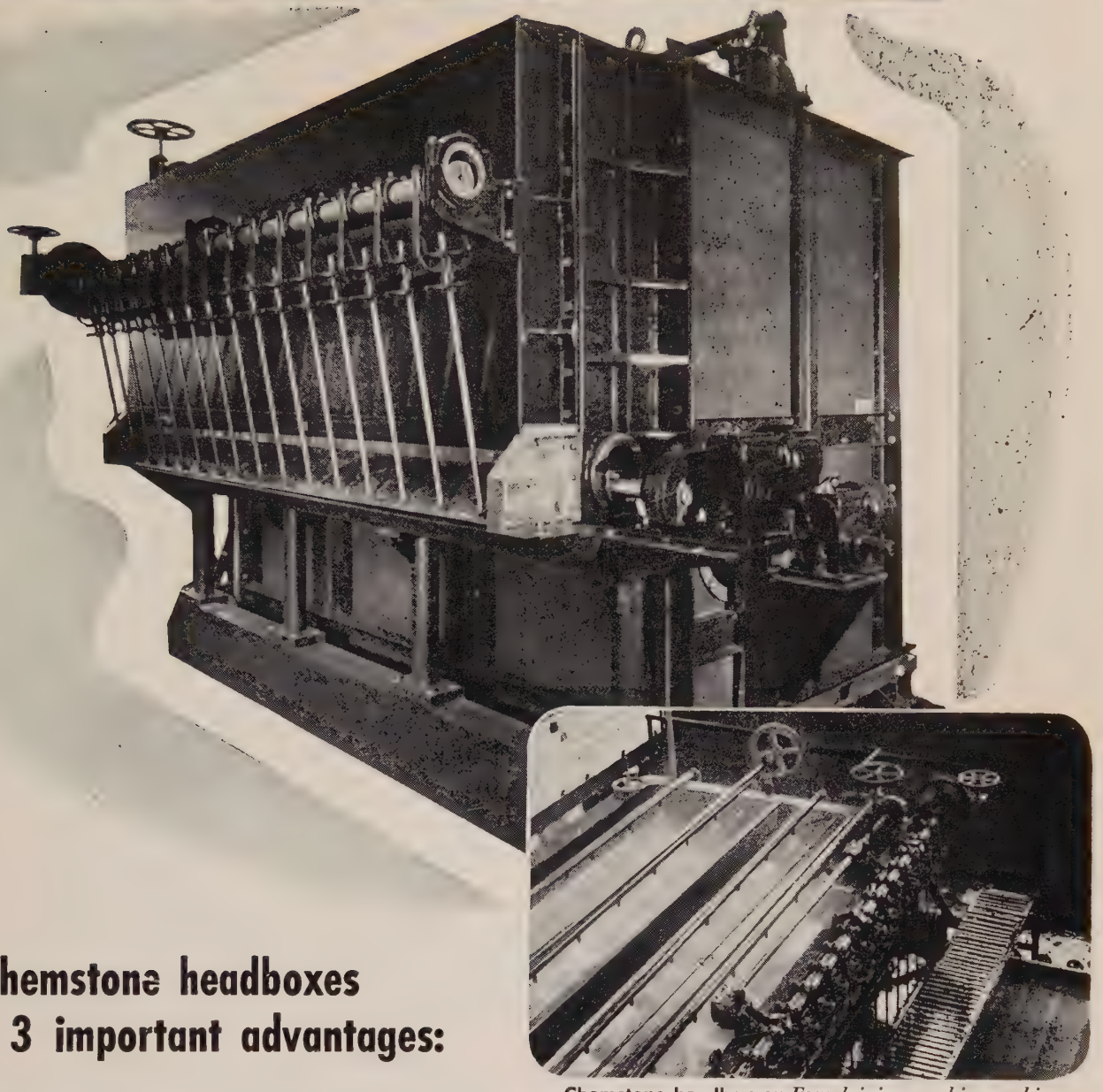
Dimensionally stable...Clean...Chemically resistant



...Chemstone headboxes have 3 important advantages:

MADE of asbestos and cement, and integrally waterproofed, Chemstone is helping paper mill men solve the problem of headboxes, consistency regulator boxes, flow boxes, linings for wire and couch pits, and stock chests because:

1. It won't shrink or swell—Chemstone is a tough, monolithic material molded under high pressure. It has unusual dimensional stability due to its low water absorption factor. When used for headboxes and other purposes in mills, it is light but strong, provides an attractively finished job that lasts indefinitely.

2. It resists slime and bacteria—Chemstone boxes prove unusually resistant to bacteria and other surface accumulations. Chemstone stays clean for long periods, but when cleaning is necessary, it can be washed easily and quickly by a simple hosing operation.

Chemstone headbox *on Fourdrinier machine making Kraft wrapping from northern Kraft pulp.*

3. It resists chemical action—Chemstone possesses the ability of asbestos and cement products to resist chemical action. Equipment made of Chemstone is free from metallic oxides, resists both mild alkalis and acids, and is unaffected by most mill waters. For full details, write, for data sheet DS series 405, to Johns-Manville, Box 290, New York 16, N. Y.

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Johns-Manville PRODUCTS FOR THE PAPER INDUSTRY

OUR WATER RESOURCES

E. N. MUNNS

The name of Audubon is a familiar one to Americans. His study of birds and his paintings of them are classic. You may not know, however, that about 125 years ago, Audubon made the trip from Pittsburgh to New Orleans on a flat boat. His diary recounts how, day after day, while passing down the Ohio, he used to watch the fish in the clear waters of the River. He mentions how sharply their bodies contrasted with the gravel in the bed of the River.

Most people realize how great a part the inland waters have played in the nation's development. They were once the chief method of transportation, the first source of industrial power. At times, the food they yielded in abundance helped sustain an impoverished agriculture. If the history of some of the great cities is reviewed, it will be found, that many became great because they were at major water-intersections, at the mouths of rivers, at the head of navigation, or at power sites: Chicago, New Orleans, Pittsburgh, Savannah, St. Louis, Richmond, Buffalo, Sacramento. It will also be found that where ample water has been available or could easily be developed for municipal, agricultural, and industrial use, that region has prospered. The eastern part of the country is well-watered. Those areas where water supplies are erratic and undependable, in short supply, expensive, or low in quality, are retarded to say the least. Unfortunately, a considerable area of America is in this condition today.

Most of the rivers were a surprise to the early colonists. Most European waters were generally rather filthy streams, but the American waters were clear and sparkling, free from sediment and pollution as they flowed quietly to the sea. For generations, while they served merely as waterways, they remained as beautiful streams. The French called the Ohio. "La Belle Riviere," the beautiful river. Time—from then to now—has seen vast changes in the character of the streams. Today many of them are uninviting, muddy, highly polluted, and heavily utilized. The water wheel and grist mill have developed into great hydro-electric plants and gigantic industries. The flat boat and little wooden sail ship has become a quarter-mile-long series of barges, each loaded with hundreds of tons of cargo and powered by a small tug. The well in the village common has been transformed into a faucet supported by great reservoirs and filtration plants, and fed by miles upon miles of underground water-mains.

The average American gives little thought to water. When he turns on the tap and clear sparkling water gushes out, he does not realize how totally dependent he and his civilization are upon the water resource. He does not know—and perhaps does not greatly care—where the water comes from, how the earth holds it in store for him, how it has to be treated, how much he uses, or how completely he and his neighbors depend upon its abundance for power, transport, or their very livelihood. But some do know that most of the metropolitan and industrial centers have built their economy upon the almost unrestricted use of this natural resource.

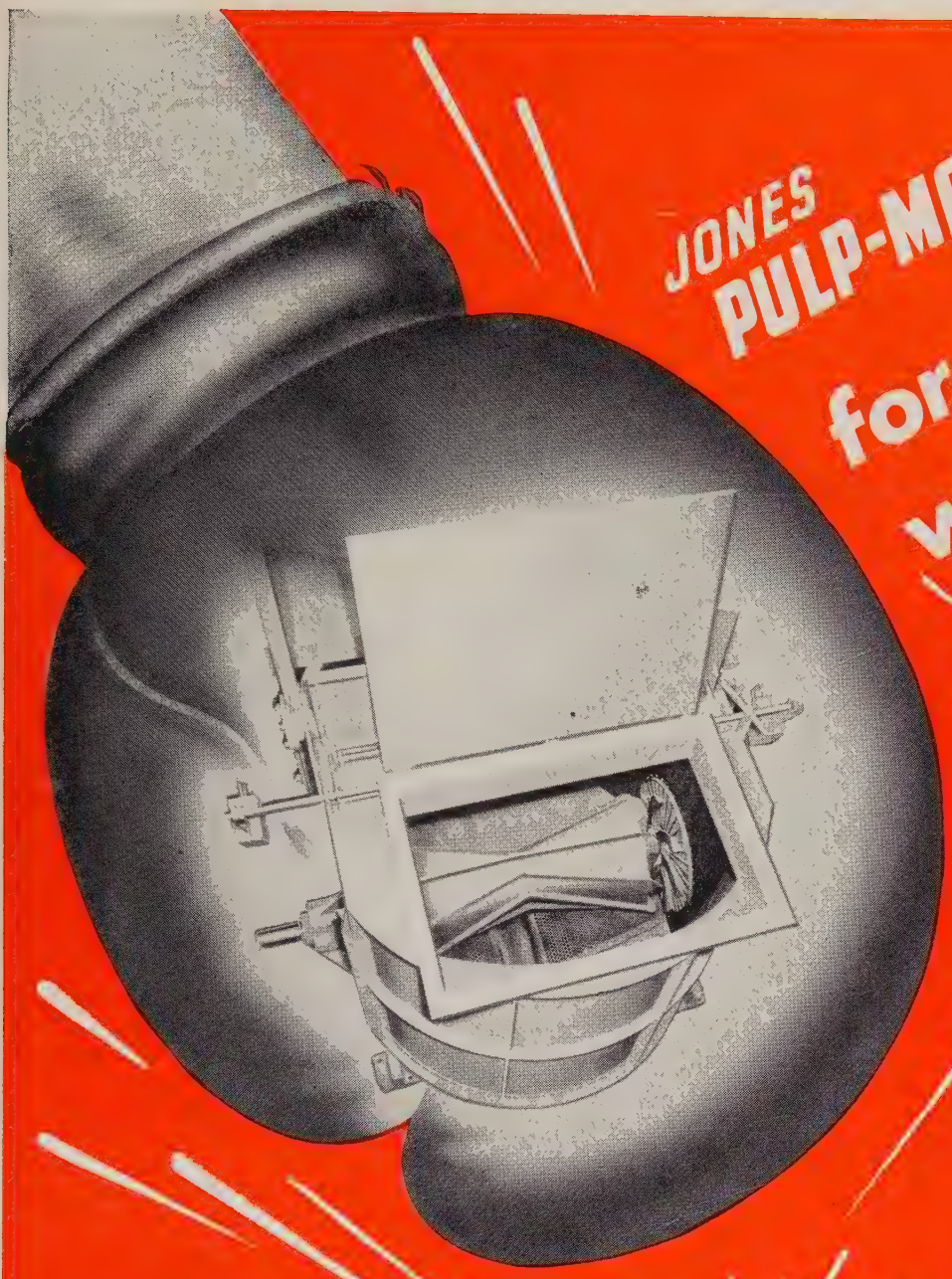
Once in a while, it is true our fellow citizen in the eastern part of the country does think about and concern himself about water. He does when there is a flood that interferes with transport, industry, or his home. He also worries as he watches his carefully tended lawn turn yellow, sicken, and die because of a water shortage. He may have cause to think about it too as he plans for his vacation or when some water borne disease develops in his community. By contrast, our friends in the Western States concern themselves about water all the time. There it makes news because the dividing line between just enough water for daily needs and real scarcity is such a narrow one. They remember that drouth in the Great Plains developed a dust bowl that for a time depopulated considerable portions of the Midwest. They know that water shortages during the past few years in portions of the Southwest have resulted in only one crop a year instead of two or three, and in some areas, have resulted in almost no crops at all. This winter, everyone has become more than a little concerned because so much water as snow will affect the possibilities for meat in the next few years.

Water scarcities are not limited to the West or to certain areas. They are known throughout the country. They have hit the Eastern States. They have been felt north and south. They are in very large part due to the adversity of the weather. They are also due to the inability of some of the land to yield a sufficient supply of clean, sweet water adequate to meet the ever increasing demands of the country's expanding economy and growing population.

Communities are plagued not only by shortages of water but also by damaging or catastrophic floods. Although all of the rivers were given to frenzied upsurges long before any white man came to this country, three centuries of settlement appear to have enormously stepped up the rate and extent of floods. Many streams, some of which did not have a pronounced flood history, now frequently overtop their banks after spring snowmelt or heavy prolonged rains. For some reason flood heights appear to be increasing as greater and greater havoc is wreaked along their flood plains. Levees, dams, dikes, and other works thrown up by man cannot tame or halt the rampaging waters. In the Northwest last spring, the Columbia River was

(continued on page 20 A)

E. N. Munns, Chief, Div. of Forest Influences Research, Forest Service, Washington, D. C.



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(continued from page 18 A)

in flood throughout a 1000 mile stretch. This winter, New York suffered. Bottomlands along the Ohio and in the South also became drenched. Yes there was much rain. But it must also be pointed out that many of the soils of the drainage basins are no longer as able to absorb, store, and slowly release water as they formerly did. Watershed conditions are no longer satisfactory.

Although floods are always serious and cause sickness, disease, and many an industrial and domestic heartache, it is the threat of water shortages for the manifold and multiplying uses of modern life that poses the more deeply serious problems. All communities are interested because they are directly affected. The town fathers must always see that water supplies keep ahead of city growth and demands. They constantly are on the look-out to seek larger, more dependable higher quality sources. Hence, they must keep reaching out farther and farther to secure their communities to preempt rights to more distant water supplies.

Like the struggle of desert tribes for the rare oasis, present-day competition for water is leading to many bitter and angry disputes. Los Angeles, desperately coping with local water shortages, has taken the entire flow of the Owens River. It, and other communities in southern California, are now tapping the Colorado River 250 miles away. California is now engaged in a dispute with the other Colorado River Basin States for rights to additional water. All is not quiet along the lower Rio Grande. New York City already has been in the courts with Philadelphia to protect her rights in the Delaware River watershed. It is also understood that it is casting envious eyes upon the waters of the Connecticut River which Boston claims as its own.

Many sections of the country, east and west are suffering from declining ground water supplies. Wells that farmers have been using for years have been failing in the Central States and in the Piedmont. The ground water under the City of Louisville has declined 40 feet in the past 10 years. A considerable acreage of irrigated land in the San Joaquin Valley has gone out of cultivation completely because the water table has dropped below the economic limit of pumping. In other areas, the draft on underground supplies has been so heavy that salt water has replaced the fresh making the water unsuitable for irrigation or domestic use. Such troubles are plaguing some of the East Coast cities today.

Many industries are well aware of water supply problems. Just prior to the war, the steel industry was in serious trouble because with increased production, there was insufficient water to cool steel. And what was worse, the temperature of the smaller volume of river water available to downstream plants was raised so high by the upstream mills that a serious decline in production took place. It takes around 65,000 gallons of water at 40°F. to cool a ton of steel and that for about each 10° increase, the amount of water needed is doubled. To relieve this situation, huge reservoirs were constructed on the Beaver River merely to supply cool water during low flow periods.

Although the question of available water supply is a matter of general concern, that of water quality is exceeding it. During the past half century, as industries have greatly increased in number and size and especially as the many chemical industries have developed, much attention has been directed toward the pollution problem. Cities have now generally assured themselves of freedom from water-borne diseases by the care exercised in filtering and treating municipal supplies. At the same time, they have created still other problems by emptying raw sewage and untreated industrial wastes into streams. Generally the community farthest upstream has the least trouble, the community farthest downstream is in real difficulty.

With the increasing pollution of the waterways have come many other troubles. Harbors have become exceedingly messy. Odors along water fronts have become obnoxious. Dangers to public health have greatly increased. Polluted waters have greatly increased maintenance costs for all kinds of shipping and have seriously damaged docks and shore installations. Youngsters die each year from such diseases as typhoid, dysentary, etc., picked up while swimming in polluted waters while others contract various infections and loathsome skin diseases. Recreational use of many streams is declining. In some streams, fish for food or for sport have virtually disappeared, indeed, some migratory species are in danger of extinction. Housewives using waters derived from industrially polluted sources spend much more for soap than they otherwise would. Several years ago the author saw some statistics that indicated the Pittsburgh housewife used from five to ten times the national average for soap, not because Pittsburgh was so dirty or that she was cleaner than her sisters elsewhere, but because of the water. Industry has had to spend great sums for water softeners. Plumbing and boiler troubles in many localities are due mainly to water quality.

There are many estimates as to the amount of pollution that occurs annually. Perhaps one of the most graphic is attributed to a national health officer who said it was the equivalent of eight million dead and badly disintegrating full grown mules.

Today most domestic water supplies are safe regardless of the source of water. For this the magic of the modern chemical and sanitary engineer can be thanked. With his thermometers, powders, gadgets, and many devices today's engineer can take water that is blackened with manufacturing wastes, rendered acid by mines, and polluted with all manner of sewage and silt, and, by washing, filtering, aerating and chlorinating, can convert it into a potable and safe liquid. One might drink it, but some might not care much for it.

Pollution is not only a serious problem where surface waters are concerned, underground sources may also be involved. When this happens, the result is apt to be most serious because of the slowness with which underground waters move and can become purified.

The author's attention recently was directed to a situation in Southern California. It appears that in June 1945, a small concern started manufacturing a weed killer, composed mainly of trichlorophenol. The waste, mainly water used in cleaning out drums and

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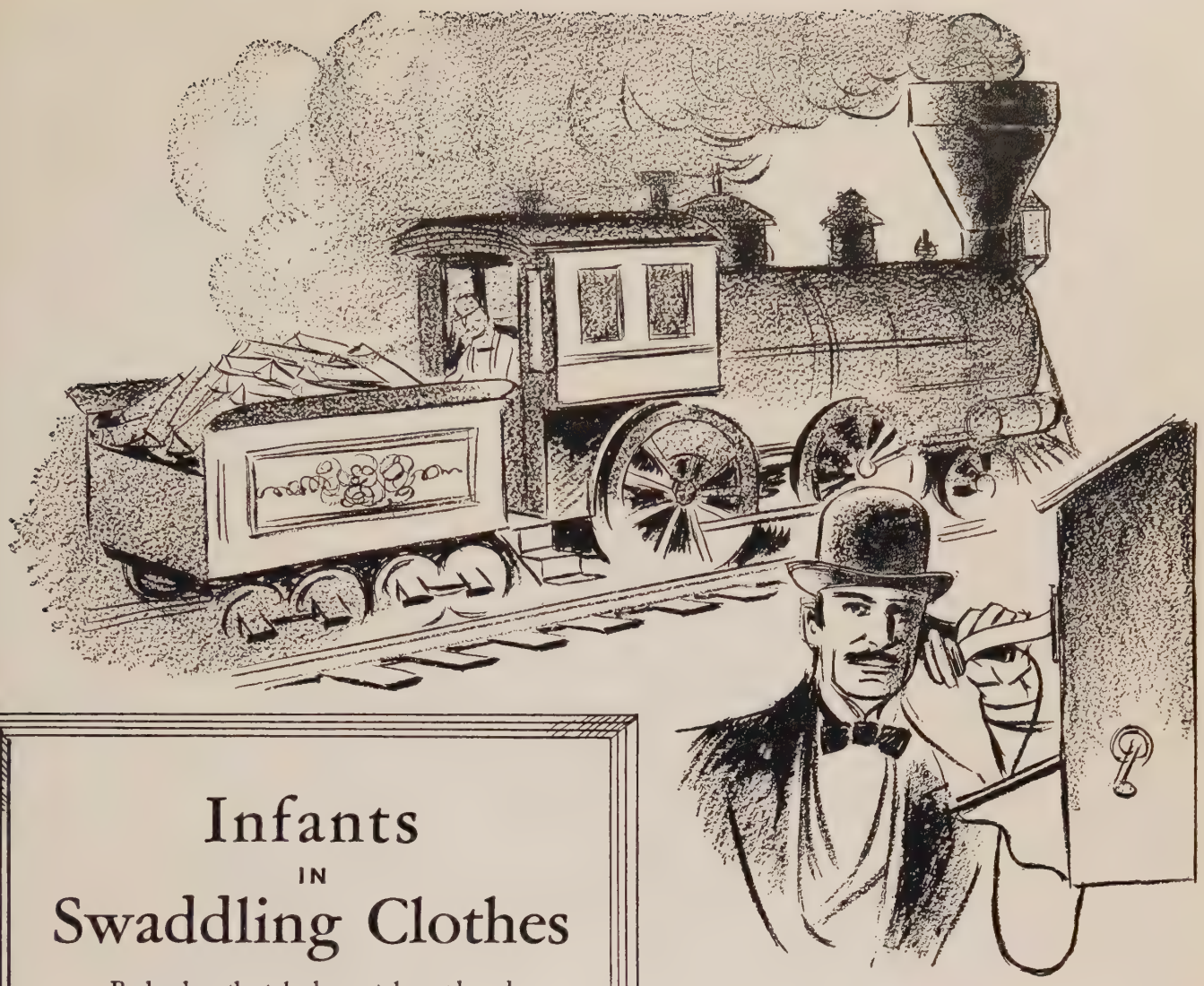

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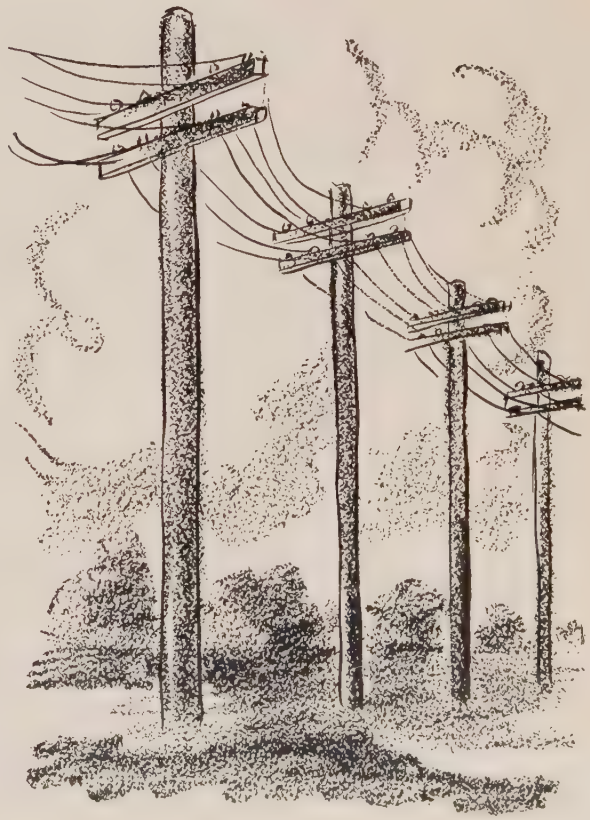

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washing down floors, plus some chemicals lost in the process, was discharged into the sewer system and passed through a sewage treatment plant. Chlorinated effluent from the treatment plant was discharged into a stream. Within 17 days after the manufacture of the weed-killer started, phenols in the water caused eleven wells in the Montebello Basin to be shut down These wells served over 25,000 people Irrigation with this water killed lawns, shrubs and some trees. Although operation of the manufacturing plant was stopped within 30 days after it started, preventing irreparable damage to the water resources of the whole Southern California underground water supply, in six months, the pollution travelled five miles and ruined many wells. Some of the wells still are contaminated.

A number of deep wells supplying domestic water to Long Island communities have been closed down recently because the deep lying aquifers are polluted.

One of the factors entering into water quality is inorganic material. This is primarily suspended matter, mostly silt or, more properly, finely divided soil particles, the product of land erosion. There has been a steady decline in water quality from this source since the days of settlement. Not only has there been an increase in the volume of the silt. but the size of the particles has been increasing as well. The author had not appreciated that the matter of particle size was giving water-works people much trouble until very recently. According to a municipal water engineer, the silty water used to pass over the diversion dam without much trouble. In recent years the particles had so greatly increased in size and weight that now when he stands on the adjacent shore, he can feel the ground shake when the silt—some would call them boulders—hit the dam. And some of these "silt particles" are so big, he avers, that not only could he not get them into his test tubes, but he had to use a power shovel to move them from the intake.

INTEREST OF PULP AND PAPER INDUSTRY

The pulp and paper industry has a dual interest in the water resource. It is directly and immediately concerned because of its industrial demands. It needs an abundant supply, good quality, and constancy in availability. It is also directly concerned because it usually disposes its wastes into streams, thereby often adversely affecting the interests of others and the public.

The industry is concerned with the available supplies because it is among the heaviest water using industries in this country. Statisticians tell us that it takes around 85,000 gallons to make a ton of pulp by the soda process and about 65,000 gallons per ton produced by the sulphate process. About 40,000 gallons of water are needed in converting pulp into paper. As paper products are remanufactured or reclaimed an equal or greater volume of water may be required.

The problem of a continuing water supply however is a serious one to the industry. The author has been told that before some recently established mills finally decided upon a location, they spent about as much time investigating the water resource as they did the forest resource. They had to be sure that at times of drought and low water flow, there would be an adequate supply of good quality water available to maintain the mill at full capacity. Where dependence was placed upon ground water, they had to be satisfied that even if new industries tapped the subsurface aquifer, there would be a reasonable expectation that the supply would be ample or that wells then could go deeper. Those mills that did not adequately investigate their water supply may one day greatly wish they had.

Water quality is an important factor. We are told that one plant manufacturing a special type of paper, spent years testing the quality of the water throughout the country, surface and underground, before it found water of just the right quality. When recently in Poland, the author discovered a paper mill which before the war had become increasingly concerned because of the development of a chemical industry in the watershed above it. In some way it was contaminating the water. Under the present type of government now in power, the chemical plant has not been allowed to rebuild on its earlier site so that the paper mill would not have to deal with contaminated waters. In Poland, paper is one commodity in such general demand and in extremely short supply, that the industry was given government protection.

One item with which all mills using surface water must contend in greater or less degree is that of sediment. Because of the heavy silt load of some streams, it is about as essential for some mills to filter their water as it is in a municipal water works. Only in this way can objectionable solids and colors be removed from the water.

In addition to supply, the industry is gravely concerned with its waste problems. In common with a number of other industries, the objectionable characteristics of some of the effluents are due to suspended matter or dissolved substances that can be precipitated with or without the use of chemicals. Most such wastes are susceptible to precipitation and filtration. These processes are similar to those used in many water and sewage treatment processes and there is abundant information relative to them. Many of the effluents of the pulp and paper industry fall into this category. But sulphite process is a matter of major concern to all sanitary officials because of its well-known polluting characteristics. About half the wood goes into the waste liquor, made up of calcium salts of lignin, sulphonates, sulphites, wood sugars, lime, etc. By using magnesium hydroxide as the base and adding sulphur dioxide, it is possible to recover the hydroxide by burning off the organic matter and calcining the magnesium sulphite to oxide Such processes are at present too costly for reconverting old plants. However, by using the magnesium salt, it is possible in new sulphite mills to solve the waste problem much as it has been solved in the sulphate and soda processes.

Various degrees of recovery of fiber now appear possible depending on the type of control adopted. Under good controls, the losses can be reduced to 1%

(continued on page 26 A)

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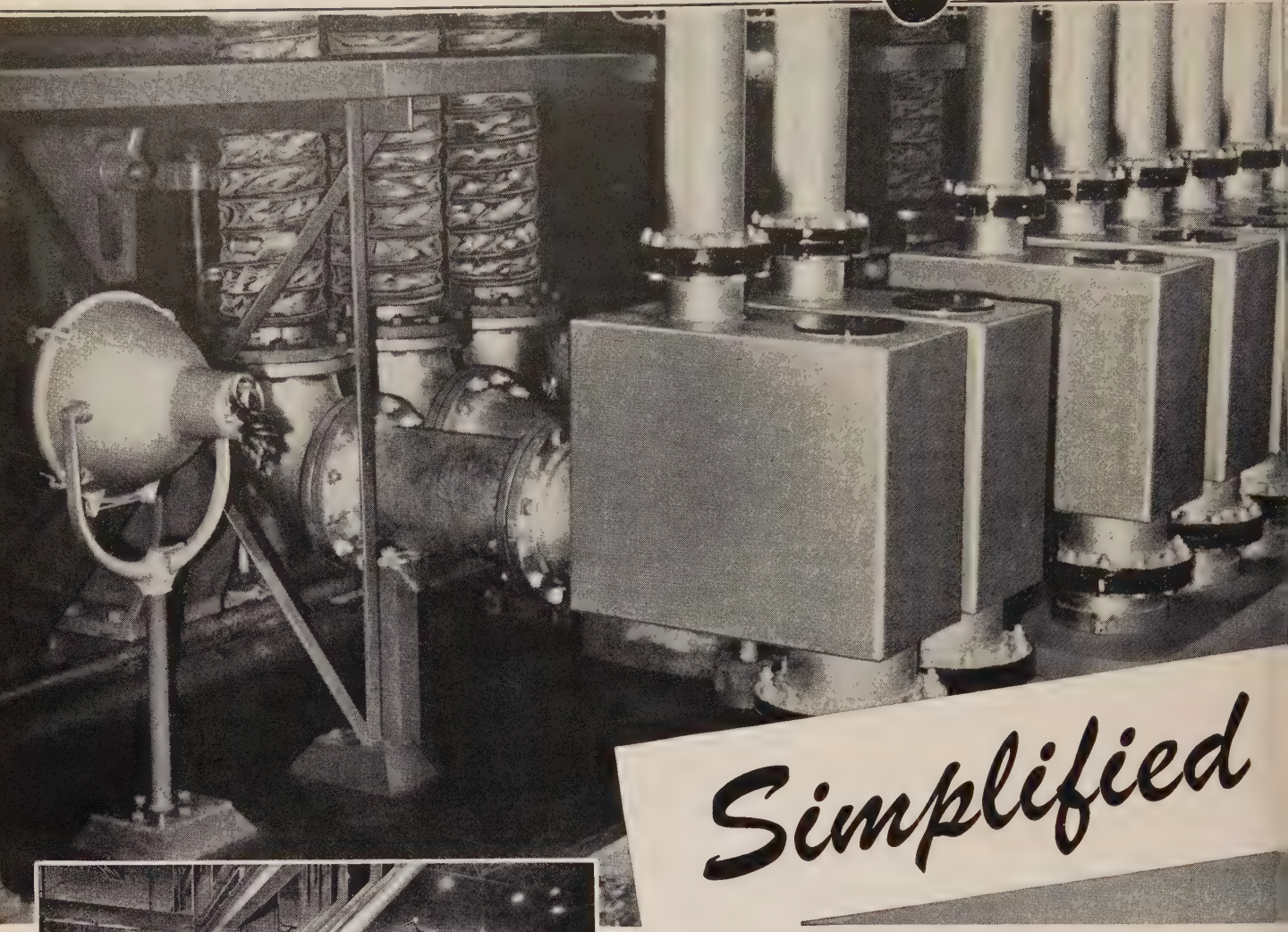

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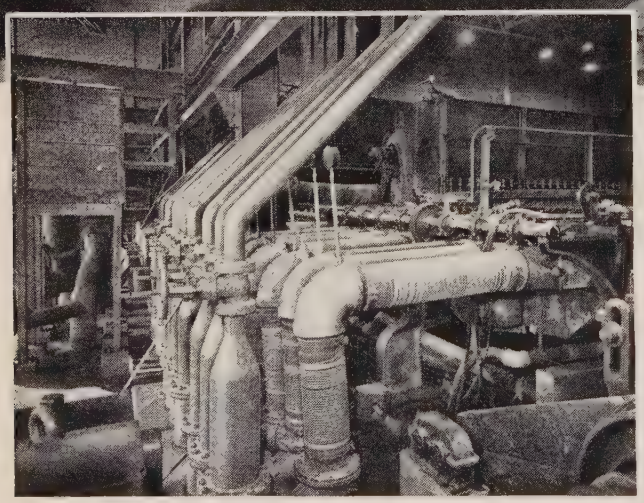

Above: new fourdrinier suction box connections on the latest Puseyjones Machines are simple, flexible.

Below: conventional cumbersome suction box connections were often a source of trouble.

Suction Box Connections

In the new Puseyjones Machines, each fourdrinier suction box is connected to the air and water header by a simple, single flexible connection. Gone is the cumbersome double hose connection that has always been a source of trouble and an eyesore to the machine operators.

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WET-STRENGTHEN your paper with Uformites

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Too bad—especially since UFORMITE 475 gives high wet strength plus maximum absorbency at low cost. As little as $4 per ton of paper boosts wet Mullen values 300%, raises dry Mullen and fold values 10 to 30%, and increases wet rub and scuff resistance, wet and dry tensile.

In paper toweling, UFORMITE 475 eliminates the see-saw relationship that has made a strong, absorbent towel a hard-to-realize ideal. In twisting tissue, too, the resin prevents breakage on paper-twisting machines. And in bags; reproduction or printing papers; glassine; tasteless, odorless, grease-proof wrappings, the UFORMITES provide the high wet strength your customers want.

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(continued from page 22 A)

or less, which would mean for many streams a wonderful clean-up.

Earlier attention was called to some of the over-all water problems. That we have them is widely known but the major causes behind them are not generally understood. That land use or abuse of the cover that clothes a watershed is deeply involved in such things as floods, drouth, sustained flow, inorganic pollution, etc., may come as a surprise to many. Conditions on the watershed may affect the size of your water bill. Because of floods, they may affect the demands made upon you for contributions to relief agencies. Because of purification costs, they affect your taxes. They affect you as water consumers, as victims of floods, as citizens. And, should it happen that you are a fisherman as well, they affect you perhaps most seriously of all.

Improper agriculture is first on the list of the causes of watershed deterioration. Careless methods of cultivating land has been a prime factor in causing poor water flow conditions. Soil that has not been properly handled will quickly loose its porosity and much of its water holding capacity. Such soils deliver far more water per acre in a shorter period of time than the original wooded slopes. This rapid delivery greatly increases flood volumes and flood peaks. To the extent that the amount of storm run-off water is increased, there is a corresponding decrease in the amount which would otherwise get into deep soil layers, into rock crevices, into underground basins. Lacking full replenishment of the deeper soil layers, there is less water available later for springs and seeps, for stream flow, and for underground storage. So not only is the flood run-off increased, but the opportunities for a greater flow during time of low water flow or drought are greatly increased. Then, too, if the underground basins are not fully recharged, the ground water is bound gradually to decline under heavy pumping, even as a storage battery gradually weakens under heavy use.

Another important factor is fire. Many of the little and so-called harmless woods or brush fires cause damage to the watershed far beyond ordinary realization. The precious ground cover, the litter, the humus, all of which are so important in destroying the hammering impact of the raindrops, is lost. The humus, home of myriads of small creatures (microarthropods), insects and animal life, is destroyed. When the forest fire develops into a conflagration practically all the surface cover is destroyed.

Practically every burned area is a potential flood or silt source, and to the extent that a watershed has been damaged by fire, so has the water resource. All use the phrase "fire and flood" without thinking. Our forebears who developed the term recognized that the two disasters are often linked: floods often follow fires on a watershed. Of this there are repeated experiences, and many California communities now get the jitters, and rightfully, when their watersheds are touched with fire.

The result of forest fires is much the same as that following improper cultivation methods. Surface runoff is increased moisture absorption and percolation is greatly decreased and less water is available for later use.

Forest fires which raged through the Northwestern States over the past century played an important part in the Columbia River floods. Hundreds of thousands of acres of high mountain land, its cover destroyed by fires sinces the turn of the century, quickly released their snow water last May and June, while adjacent unburned alpine forests retained some of the winter's accumulated snow.

Too heavy use of pastures and ranges by livestock is also responsible for poor water flow conditions. While the effects are much the same, the processes involved are somewhat different from those just outlined. In cultivating, all the protecting surface vegetation is lost. Forest fires destroy the ground cover, the litter and the humus. Livestock do not necessarily destroy vegetation, they mow it. However, they take so much of the ground cover that there is no waste plant-material left to protect and enrich the soil. In addition the weight of the animals compacts the soil. This compaction prevents rapid absorption of water. It also drives out soil air. As a result the numbers of all forms of soil life are decreased and plant roots do not penetrate so deeply. Consequently, heavily used pastures and ranges tend to develop a shallow sod. Compacted sod-covered soil, encourages runoff and discourages absorption, and results again in excess runoff, in decreased low water flow, and in declining water table.

Logging operations have materially reduced watershed values. In far too many areas, stands of timber have been heavily cut, leaving an inadequate stand of trees to maintain the ground cover or to restock the land. Soil is then exposed to sun, wind, and rain. Even though foresters have been concerned with timber cutting for years, it has only been recently that they have become aware of the fact that they have little data to indicate just what the effects of lumbering may be on the water regime. One study in New England revealed that between 80 and 120 years are needed to rebuild fully the soil following clear cutting. Studies in the watersheds of both the Potomac and Pee Dee Rivers have shown heavy cutting to be responsible for loss of litter and humus, and for damaged soils incapable of providing full protection to the water resource.

Some of the damages done in logging are due to soil compaction. The increasing use of heavy caterpillar tractors, bulldozers, and comparable logging equipment is resulting in converting up to 50%, of the cut-over area into what might be called a "logging road." And when forest soils are compacted, they, like overgrazed pastures affect adversely the water resource.

There is one other factor operating on cultivated, burned, and compacted soils not touched upon. It is also one which greatly affects the water resource. It is soil frost. Cultivated soils, burned soils, grazed soils, and compacted soils alike freeze deeply in the winter. Comes a sudden thaw, and the released snow water, unable to penetrate into the soil, must perforce runoff. It has been now two years since an extremely light ground fire occurred in Rock Creek Park in Washington. It merely burned the loose surface litter. By probing around with a blunt stick during the winter, it is possible to outline the area that was burned

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(continued from page 26 A)

from that unburned, for the burned area still freezes while the litter and humus-covered soil is unfrozen. The prod pushes easily and deeply into the unburned and unfrozen soil but the hard ground of the burned area quickly reveals where the ground is frozen.

Those who live in the salubrious frozen north could easily satisfy yourselves quickly of this phenomenon in a similar fashion. We also suggest you try contrasting by this method the permeability of the soil in ungrazed old-growth woods, with that of a pasture or grazed patch of woods.

There are many other contributory factors to poor watershed conditions. Some of the more troublesome are roads, mining and smelting, drainage, encroachment upon river channels by agriculture and industry, etc. These operate to a greater or lesser degree depending upon location, terrain, soil, and many other factors.

In the discussion of watershed abuses, it has only barely been mentioned that land use practices can and do cause serious pollution. Yes, these same practices of improper cultivation, fire, overgrazing, the lack of care in logging, etc., that result in irregularities in water behavior and supply, also cause inorganic pollution. By and large, they are the great contributors to silt in our streams and the cause of many heavy losses to all who use water—agriculture, industry, commerce, recreation, and the public as a whole.

Studies have shown that the shoaling of harbors, the filling of river channels, the loss of storage in reservoirs, and related sedimentation troubles can be directly and immediately traced to abuse of the land and its cover. One study revealed that up to the time of the Civil War, tobacco production resulted in the removal of about 8 inches of top soil from the eastern half of Maryland. Near Falls Church, Virginia, just above Washington, D. C., a stand of pine about 150 years old, was recently cut for pulp. This stand grew on a piece of land that had been deeply incised by gullies from 10 to 40 feet deep, undoubtedly land that had been "worn out" by tobacco cultivation and abandoned before 1800. The many reservoirs in the Piedmont section that are now filled with debris attest to the large quantities of soil which have been eroded from hillsides.

That improper grazing is responsible for such sediment in many streams and reservoirs is clearly written on thousands of acres of land throughout the western portion of the country. Prior to the introduction of the great cattle herds that replaced the buffalo only about 75 years ago, great expanses of grasslands stretched for hundreds of miles without a break in the soil. Overgrazing and trampling initiated gullying on a grand scale. Creek bottoms which offered no barrier to cattle or their herders only a few generations ago have now become deep arroyos that horsemen have difficulty in crossing. Following cover removal and trampling, soil that had not been disturbed for tens of thousands of years has been removed from mountain tops. So much damage has been done to some watershed lands that drastic reductions in range use are essential if the water resource, on which the West much depends for its very existence, is to be maintained.

Fire as an agent responsible for heavy sediment damage should not be underestimated. It is possible that Santa Barbara which was almost without water last spring and summer, might have had water had it not been for a fire on the watershed from which it gets much of its domestic supply. Sediments, following a single great fire, destroyed nearly half of the capacity of the city's reservoir and a considerable volume of water in the reservoir this past year could not be drained out because of the heavy deposits. About 15 years ago, soil and rock eroded from mountain watersheds caused a loss of some 34 lives and property damage of $5,000,000 following a chaparral fire near Los Angeles.

LOGGING OPERATION

Logging methods followed today in many parts of the country are responsible for dirty streams. Lack of care in skidding logs, even the small ones from which pulp is made, often starts a chain of circumstances in motion that results in heavy soil loss which may increase with the years. A logging operation in the Southern Appalachians which was taking small-sized logs from the woods increased turbidity from 5 to 10,000 p.p.m. and has caused what was formerly a clear stream to run turbid for the past several years.

Some may be fishermen. Those who are know that where dissolved oxygen falls below 3 p.p.m. fish are generally absent though one can find an occasional carp, buffalo, or sun fish. Where the dissolved oxygen runs up from 3 to 5 p.p.m., fish are more abundant but show a tendency to deformity and are often sick or parasitized. Where the oxygen does not fall below 5 p.p.m. the fish are varied, in great number, and healthy. If game fish are wanted, the water must have the oxygen as close to the saturation point as is possible. It is in such waters bass, the fighting pike, and the wily trout are found.

The higher the water temperature, the less oxygen it contains. Some may know that fish have temperature requirements more exacting than those required in pulping research. For some game fish, water, temperatures around 80° are lethal.

The game fish lay relatively few eggs as compared with some other varieties, and the eggs are laid in nests which are guarded by the parents. Sludge will cover the eggs so they cannot hatch, and mud and silt are just as disastrous to the eggs as sludge.

Some individuals may be guilty of following the State trucks which are stocking streams with legal sized fish. The author counted 22 autos following such a delivery truck about to release its load into the Gunnison River in Colorado.

But what has all this to do with the watershed, may be asked? Poor watershed conditions regardless of the reason may and does affect fishing far more than over-fishing. First of all, heavy land erosion often brings in the silt that buries the eggs, and when the current population of fish have been removed, the stream is "fished out."

Heavy erosion also washes into the stream masses of vegetable matter—leaves, debris, etc.—which may be partially buried. The B.O.D.—bacterial oxygen demand—of this decaying vegetable matter may be sufficiently high to remove much of the oxygen from

(continued on page 30 A)

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At present day costs of logging and cooking, a 10%, 15% or 20% increase in yield means a lot of dollars saved every day. Further, it means fewer trees need be cut to maintain your mill's present output of paper, thus the uncut trees can grow bigger so that each will produce more pulp.... All this is obtained by High Temperature Alkaline Refining with Sutherlands. Commercial installations on kraft and sulphite pulps prove that yields of 60% and over are possible and this means savings of about $6.00 per ton of pulp, at present day costs of wood, power and chemicals. In addition, high strength with high freeness is obtained, which means increased production on the paper machine due to better drainage, plus improved quality.... As pioneers in the development of pre-refining at the pulp mill, our recommendations can be accepted as sound and practical. One of our sales engineers will be glad to give you further details.

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SUTHERLAND

(continued from page 28 A)

the water causing fish to migrate if the lack of oxygen does not kill them. Then too, turbid water warms up fast. Turbidity may raise the stream temperature sufficiently to release much of the oxygen present in the water and so to create conditions unfavorable to the fish. Turbidity also keeps sunlight from the bottom reducing or preventing the growth of fish food, another factor which helps depopulate streams of game fish. Then too, the mud which blankets the bottom, buries much fish food.

Cutting practices and logging methods can be and also are responsible for impoverished fishing. Cutting practices that remove trees that border lakes and streams, deprive the water of shade, thereby increasing water temperature. They also remove an important source of fish food, for many insects fall from the trees into the water, and many flying insects that flit about in overhanging branches also fly close enough to it to be caught. Aldo Leopold once told the author that the reason for the disappearance of the white fish from many small lakes in Wisconsin was due to clear cutting practices which raised the water temperature too high for the fish, and which eliminated much of the food on which the fish depended.

THE CONNECTICUT RIVER

To consider what all this means in a sample stream, the Connecticut River is taken as an example because its history is rather well known.

The Connecticut is a river whose watershed has greatly deteriorated. The stream has also been polluted by sewage and industrial wastes of many kinds. Until fairly recently, it supported an important fishing industry. Today the migratory salmon, shad, sturgeon, alewife, and lamprey eel have been greatly reduced in numbers or have disappeared entirely, and with their loss has gone the fishing industry dependent upon them. The population of such nonmigratory fish as brook trout, smelt, perch, pickerel, and white fish has dwindled down to a fraction of what it was formerly. Some streams have been, in common parlance, "fished out." The fact is, that if stream conditions were bettered, the river and its tributaries could support a trout population of 1500 fish per mile of running water.

Floods in the Connecticut have been extremely damaging to aquatic life. This is particularly so in the tributaries which comprise about a third of the trout-fishing waters, and about a fourth of the warm-water fishing waters of the four States in which the Connecticut River Basin lies. In these tributaries, and in the main stream as well, stream beds are subject to rather frequent flood scouring. This scouring process destroys considerable fish and their supporting equatic flora and fauna. These floods also alter the natural stream environment, i.e., the protective bank cover, pools, spawning grounds, etc., so that the streams are becoming less suitable or are totally unsuitable for fish life. Flash floods, which raise and lower levels in the streams, leave many fish large and small stranded in temporary pools from which the water gradually seeps or evaporates away. Some of these flash floods also sweep into the stream, leaves and other vegetable matter, which partially buried, removes needed oxygen from the water. Occasionally other toxic material is washed into the stream as well.

The Westfield River, a tributary of the Connecticut in Massachusetts, is a stream once widely known for the excellence of its trout fishing. Floods, irregular flows, and silt have seriously affected its natural production as well as its ability to sustain a large fish population. At the present time, the State of Massachusetts is annually stocking the river with approximately 50,000 legal sized trout. Of these some 20% are lost each year as a result of poor environmental factors growing out of impoverished watershed conditions alone.

In the Connecticut River as a whole, some 600,000 legal-sized trout are used annually to restock the stream. It costs about $1.50 to raise five legal-sized fish or 1 pound of trout. The loss of 20% of the fish so planted amounts to $36,000 a year. To the fishermen it might mean more if it was said that poor watershed conditions resulted in the loss of 120,000 planted trout each year. If each fisherman spends 3 days a year at his favorite sport and catches 30 fish in the period, he might be called a good fisherman. But the 120,000 fish lost would mean that some fishermen, $1333^1/_3$ of them, had to show their empty creels and tell their friends of the fish that got away instead of bragging of the 30 fish to which they were entitled. And these $1333^1/_3$ fishermen could blame their lack of luck not on their lack of skill, not on the crowds that were fishing, but upon the conditions of the watershed lands. These conditions had robbed them of their share.

At present, the attention of most sanitary engineers and health officials are directing public attention to industrial and domestic pollution. They have succeeded in focusing the attention of recreationists also upon these pollutants, hence the constantly growing public demand for pollution abatement programs.

Many accusing fingers have been pointed at the pulp and paper industry. Many a verbal rock has been hurled in its direction. The industry has already gone far in its efforts to reduce poisonous effluents and to eliminate wastes. Some of the processes have been costly to adopt and to install. Some recovered materials have been converted into marketable products but the maximum demand for these probably will take care of only a fraction of the wastes from which they were derived. Drastic legislation which has been proposed from time to time would not necessarily solve the problem, though as technicians, it might be hoped that it would stimulate greater research into other methods, other processes, and other products. Such controls might be a severe blow to the industry without providing any real solution. It is believed that though it has yet far to go, the industry is going about as fast as possible in its efforts to reduce its industrial wastes.

While the industry is directing much attention to controlling its industrial pollution, the Forest Service is not at all sure that it is much interested in its watershed activities which promote the production of inorganic pollution and which affect adversely the water resource.

The industry takes the wood from thousands of acres of forest land each year to supply itself with the 20 million cords of wood it requires. The industry

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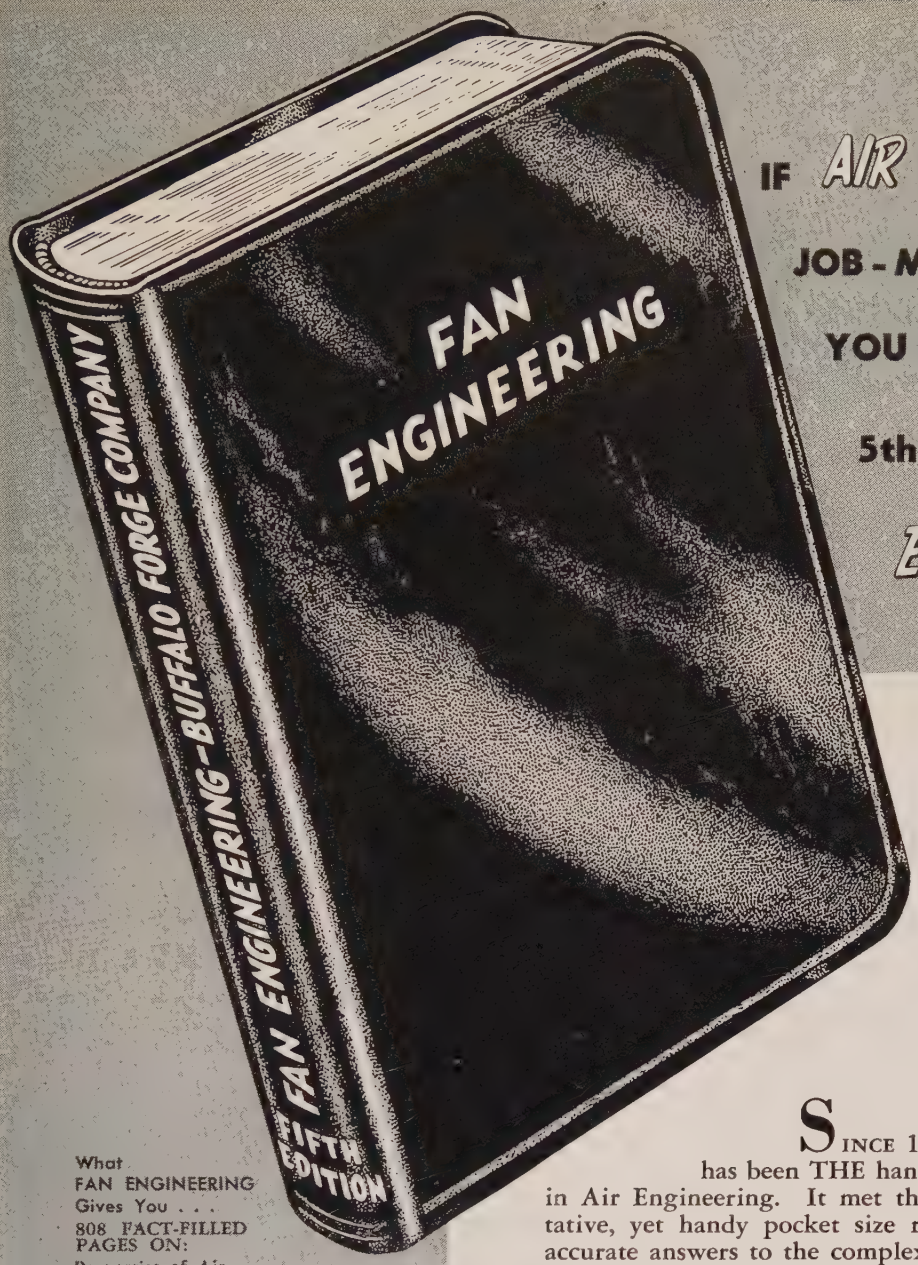

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(continued from page 30 A)

is an ardent supporter of forest fire control. It has aided the States and the Federal Government in developing an ever increasing efficient organization for controlling forest fires. This is all to the good. Some cutting and logging is done under conditions which safeguard the water and soil resources of the watershed. However, it is regretted that it must be reported that most cutting and logging is damaging to these resources and of course, any disturbance of the watershed in which the mill is located, causes damage in one way or another, to the industry itself. It could at little cost to itself go far in correcting this situation.

The industry has not to the service's knowledge taken any active interest in obtaining good agricultural practices on the watersheds in which it is interested. Part of the reason lies in the fact that the industry has not generally recognized a prominent source of some of its water resource difficulties. Another part stems from the fact that the industry believes it has little in common with farmers, though it should recognize that the greater area of forest land in the country is held in small holdings, a great many of them farms.

PAPER MILL POLLUTION PROBLEM

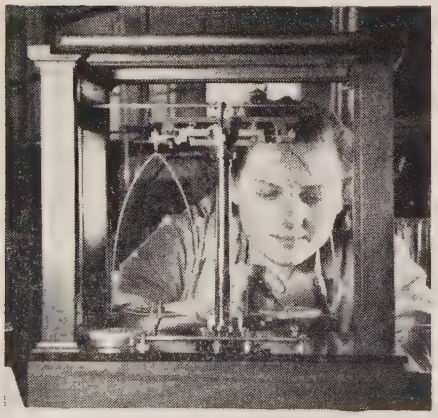
Not so long ago a Forest Service research group engaged in watershed management was asked by a pulp company for help on its inorganic pollution problem. It was explained that after the mill had been in operation a few years, their water supply had greatly deteriorated. So much silt was getting into their water supply that it was costing them around $30,000 a year just for purification alone. Occasional failures of their purification plant allowed sufficient silt to get into the mill to discolor the paper. The company was quite careful in logging the upper watershed from which the water was obtained so as not to damage the water. The company had overlooked one fact. When they laid out the townsite, they utilized practically all the available gently sloping land around the mill. They had built the school and many houses, upstream of their plant. In wet weather, autos wore deep ruts in the roads. Many of the mill hands had gardens, kept chickens, pigs, and other livestock. Naturally, the youngsters wore off all the grass on the school playground. Every storm, therefore, washed great quantities of soil and other material directly into the stream. After realizing what was the trouble, the company remedied it by removing all the structures and depopulating the area. It then reforested the area as quickly as possible. Since all this happened, the purification cost is now less annually than it was for one month.

Amusing as this incident was to those who were acquainted with it, it does show that research sometimes pays off. It is not advocated that the industry depopulate the watersheds from which it gets its water supply. That might prove to be a huge undertaking, too costly even for paper companies, some of which are understood to be showing a profit today.

The suggestion is made, however, that the pulp and paper industry can demonstrate greater interest in upstream conditions. It can help the fishermen, communities, and the public generally understand that poor water resources and poor lands go together. It can bring about a realization that the sportmen and the public have a mutual interest along with industry in obtaining good watershed conditions. It can assist programs designed to restore and maintain such conditions. It can take the leadership in promoting wise and intelligent practices on the forest lands from which it obtains its raw product. To do this, however, they should become acquainted with their watersheds, learn how they tick, and why the water resource is what it is.

And, while attention may have been directed toward the industry rather than to the members of the Technical Association, the author would like to add that the technical men associated with the pulp and paper industry have the opportunity to influence management in obtaining better water supplies. After all, it is the research personnel that leads industry. They should lead it not only with respect to manufacturing methods and practices, but also with respect to safeguarding the industry's water resource as well. They too should know their watersheds.

An address given at the annual meeting of the Technical Association of the Pulp and Paper Industry, Commodore Hotel, New York, N. Y., February 21, 1949.



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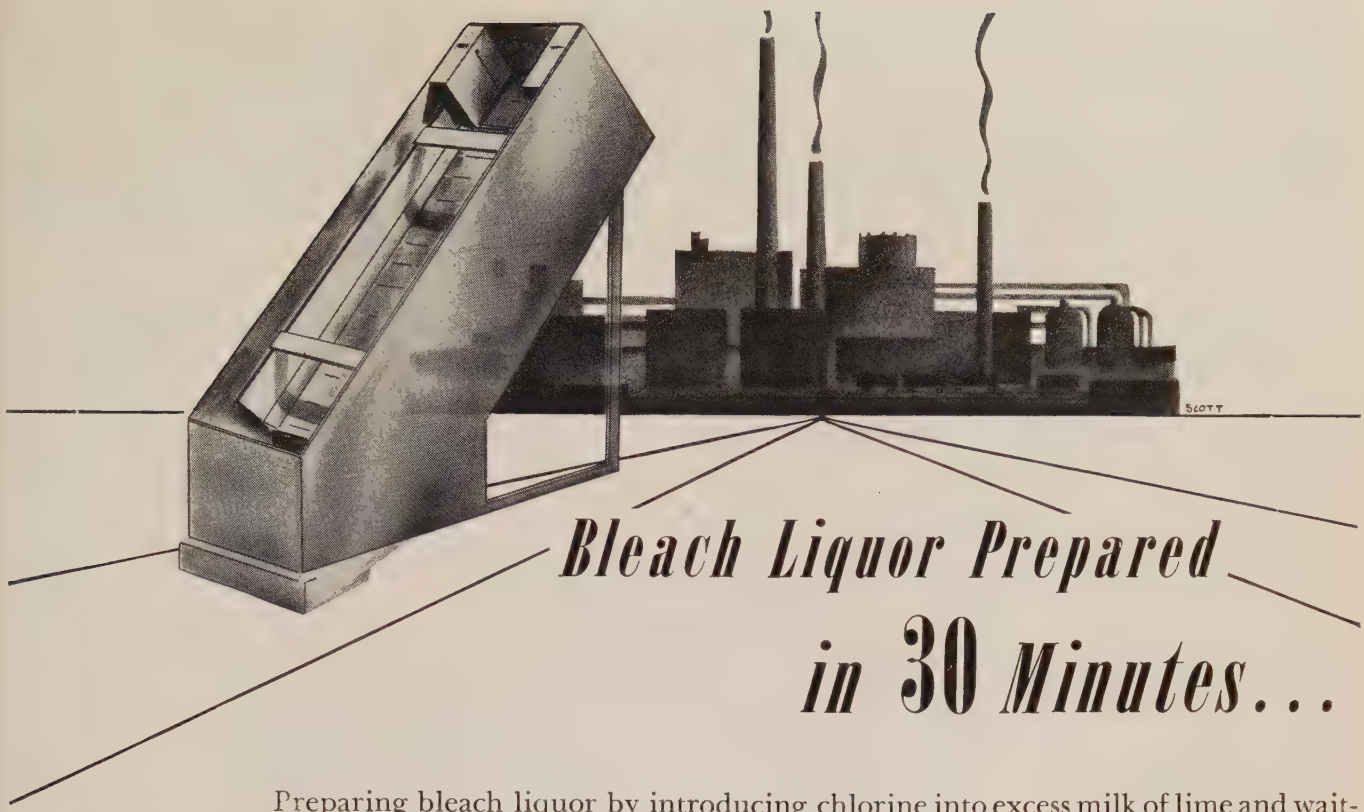

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- Hooker Bulletins 201 and 242 are devoted to a discussion of the production and use of unsettled bleach liquor and the equipment for this process. They are available when requested on your company letterhead.

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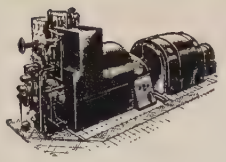
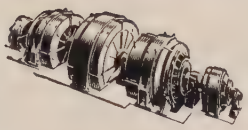
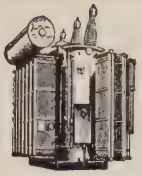

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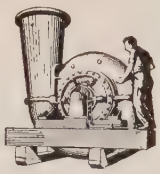
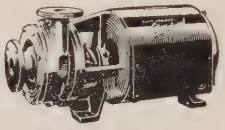

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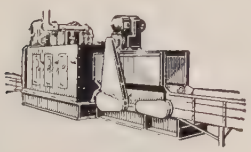
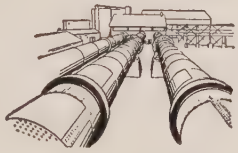

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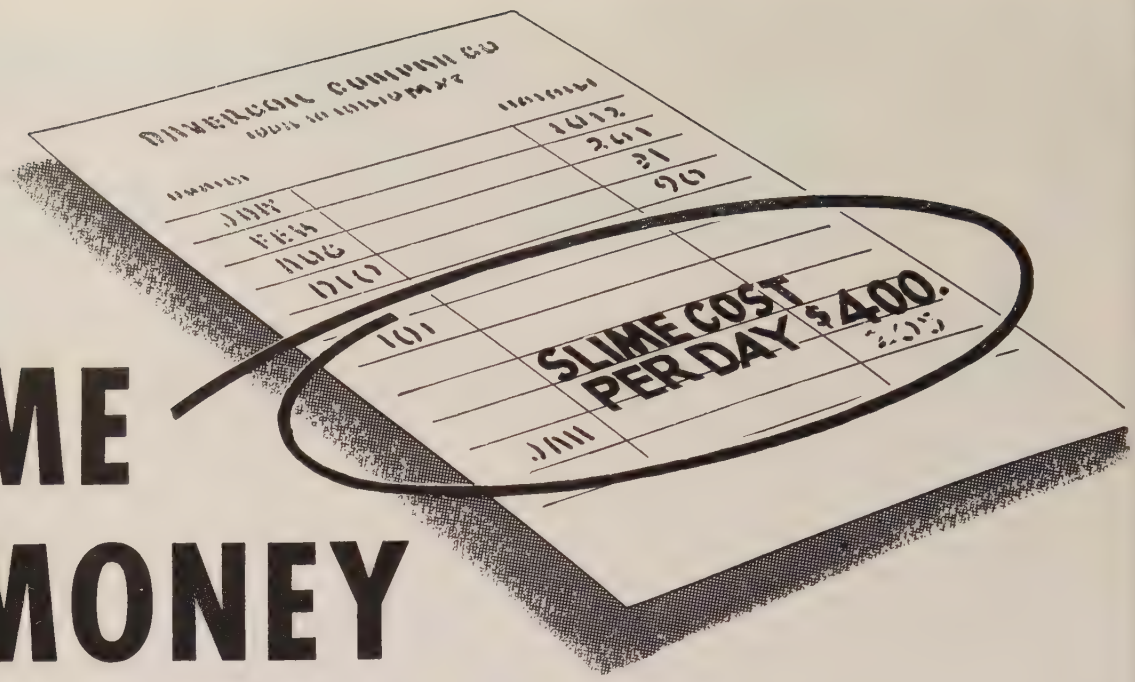

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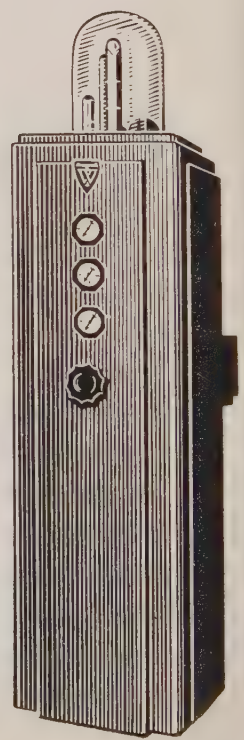

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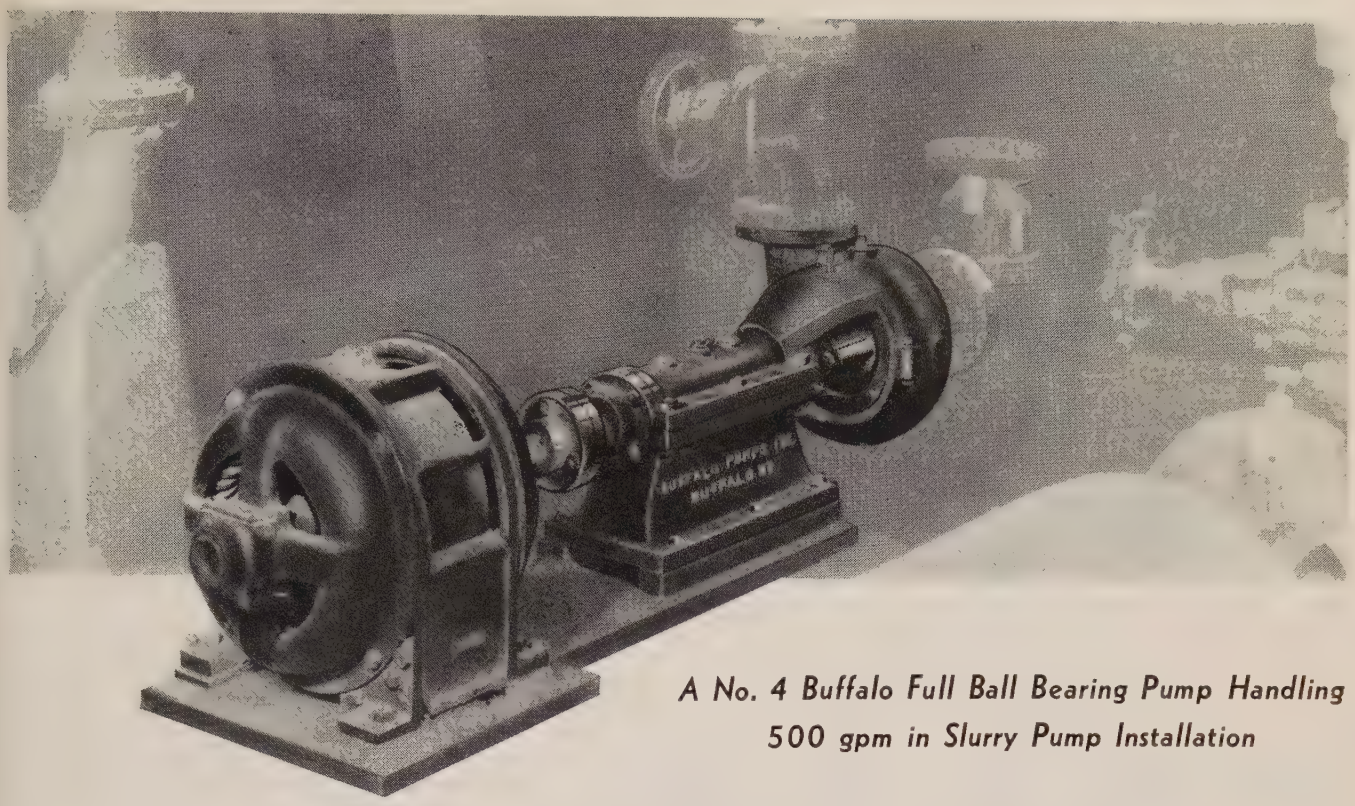

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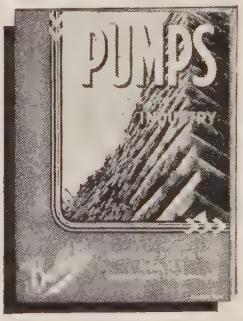

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The sticks, approximately 100 inches in length, were carefully piled in a 4 by 4 foot rack, the volume of the sample taken by measuring the average height and width of both faces of the pile. This pile was dismantled, each stick cut to approximately 50 inches in length, a ¾ inch disk taken from the center of each, then the 50-inch sticks repiled in an 8 by 4 foot rack and the pile measured.

The disks were used to determine the density and bark weight, both wet and dry, and moisture content of the individual sticks. Each cord sample was photographed after piling as 100-inch wood and again as 50-inch wood. The photographs of the 50-inch cords were analyzed for per cent solid volume by the

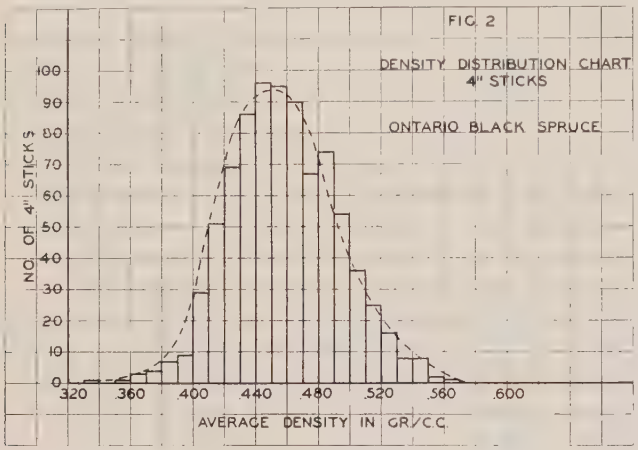

Fig. 2. Density distribution chart—4-inch sticks. Ontario black spruce

method developed by Keepers and Nekoosa-Edwards Paper Company (*3*).

The foregoing measurements provided data which were used to find: (1) average length of stick; (2) average diameter and distribution of diameters; (3) average density and distribution of density; (4) relationship between density and stick diameter; (5) relationship between cord volume and average diameter; (6) weight of bark—as per cent on wet or dry weight of wood; (7) shrinkage in volume in reducing from 100 to 50 inches length; (8) dry weight of wood per cord, (a) volume and density, and (b) wet weight and moisture content; and (9) sticks per cord vs. average diameter.

An examination of the results found shows some rather interesting relationships. It is at once apparent that normal frequency distributions occur for most of the properties studied. This was found to be the case for length, density, and diameter. Figure 1 depicts this type of distribution for the shrinkage that occurs in cutting 100-inch wood to 50 inches. The average value for this shrinkage amounts to a little over 5%. This figure closely approaches and offsets the excess volume resulting from cutting wood to 100-inch lengths instead of 8 foot, that is 96 inches.

One of the most interesting findings in this study was the relationship between diameter and density of the individual sticks. Again the densities varied widely for any selected diameter, yet when charted as shown in Fig. 2 a typical random distribution occurs, but the peak for these curves shifts toward higher values of density with decreasing diameter. Figure 3 shows this definite relationship between diameter and density. The reason why this relationship exists is not entirely clear. In general, the density of wood in a single tree decreases from the butt to the top. On that basis alone the smaller diameter sticks coming from the top of the tree would be expected to have a lower average density. On the other hand, slower growing trees in a given stand of timber would not only be smaller in diameter but higher in density also (*1*). Therefore, it would seem that the smaller diameter sticks in the shipments of wood represented by this study came largely from slow growth trees.

Since the weight of dry wood substance in a given volume increases with density, the smaller diameter black spruce wood should produce a correspondingly greater proportion of wood pulp. Of course, other factors such as cleanliness, handling problems, and preparation cost all have a bearing on the value of the wood for pulping also. The foregoing relationship between average diameter and density even suggests that wood cut to a smaller top diameter would produce more pulp. However, such a conclusion is not warranted by a thorough analysis of the data.

Others (*3, 4, 5*) have shown that the solid volume per cord of pulpwood increases with increasing average diameter of the sticks. This is undoubtedly true of wood arbitrarily selected into various diameter classes. However, the normal woods-run of timber, not separated into certain diameter classes, does not show this type of relationship. Actually a "shot gun" type of pattern as shown in Fig. 4 is obtained. The solid con-

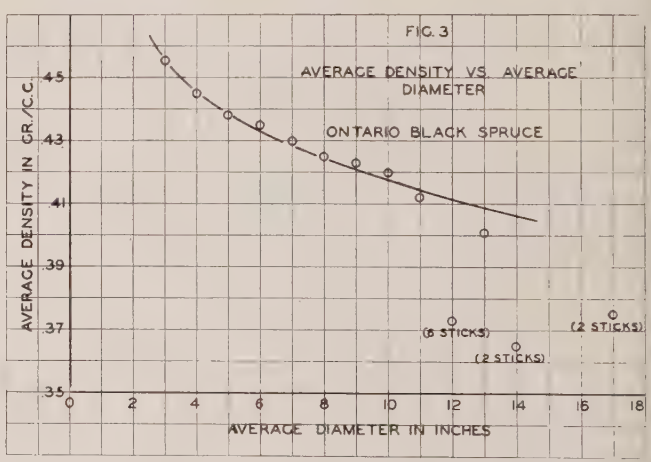

Fig. 3. Average density versus average diameter. Ontario black spruce

tent per cord on 45 cords of wood measured was found to be 107 cubic feet for closely piled 50-inch black spruce having an average diameter of 5.63 inches. Data similar to that shown in Fig. 4 were obtained also by Martin (*6*) in his studies on 1500 cords of black spruce. Therefore, any relationship between diameter and solid content per cord should be interpreted only in the light of the conditions employed in getting the basic data.

A remarkably close check was obtained on the dry weight per cord found by the two methods employed for calculation, that is using volume and density, and wet weight and moisture content. The figure for a

50-inch cord was found to be 2960 pounds in both cases.

Bark weight on the dry basis, that is dry bark based on dry wood, averaged 7.18%. On the wet basis it averaged 8.72%. These figures do not give any information on bark volume which is generally estimated to be 15%.

One of the aims of this work was to determine if relationships existed between the physical properties of the wood which would provide a reasonably accurate and simple measurement of its dry weight. Therefore, the relative solid volume in the racked cords of 50-inch wood was measured also, using the method developed by Keepers (*3*). A solid volume of 105.7 cubic feet was found in this manner as compared to 107.1 from actual stick dimensions. The difference between these two values represents an error of 1.3%. This error can be attributed in part to lack of familiarity in the use of the method and to the difficulty in getting sharp photographic definition at the periphery of the log ends.

Using the volumes obtained by the method of Keepers and the densities obtained from the curve relating density with diameter, an average dry weight per cord of 2880 pounds was found. Actual dry weight by measurements on individual sticks was 2960 pounds. Thus the error in dry weight amounts to

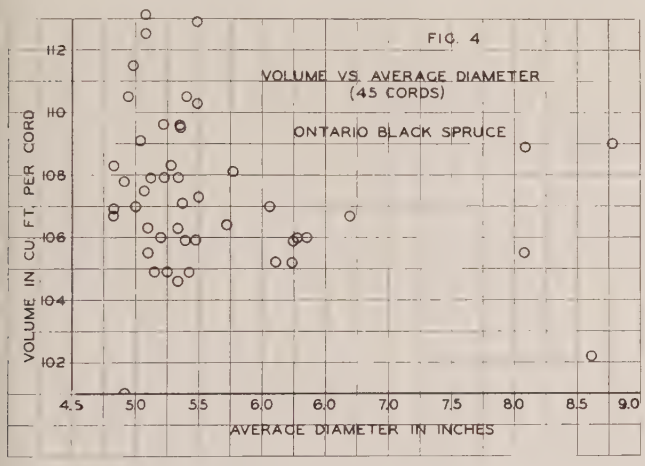

Fig. 4. Volume versus average diameter (45 cords). Ontario black spruce

2.7%. This error is partly due to the difference of 1.3% between volume by the method of Keepers and actual volume. Therefore, elimination of the volume error by further refinement of the photographic technique for measurement should provide a means of determining dry weight of wood with an accuracy very close to 1%.

The method just described for determining dry weight of wood falls short of the ideal in several respects. First, the weight is expressed on the per cord basis but it provides no information on the number of cords in a given shipment or lot of wood. In other words, it is not a substitute for scale measurement. Therefore, it is still necessary to scale the wood either by presently used or published methods or some new method, possibly by appropriate modification of the photographic method. Secondly, a simple means for determining average diameter is required. Here again

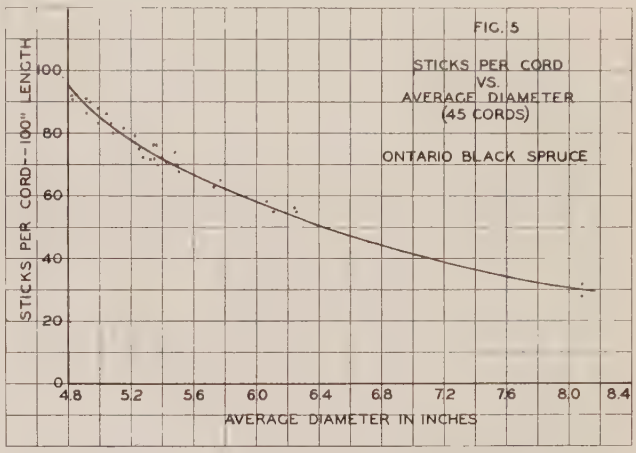

Fig. 5. Sticks per cord versus average diameter (45 cords). Ontario black spruce

the photographic technique of Keepers (*3*) combined with a sampling procedure based on the statistical methods used by Martin (*2*) offers some very interesting possibilities. The close relationship between the number of sticks per cord and average diameter as shown in Fig. 5 provides another means of measurement which Martin (*2*) has applied to pulpwood evaluation. A comparison of Fig. 5 with Martin's data on similar wood shows a remarkably close correlation of results. This independent check lends further support to the reliability and utility of the relationship. Furthermore, the use of statistical methods for this type of analysis provides a powerful tool that might well simplify the problem of adequate measurement. However, until the detailed procedures are carefully worked out the measurement of pulpwood to a high degree of accuracy remains as an expensive operation. The cost of such methods must be justified by the benefits realized from them.

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The data presented in the foregoing discussion and charts were obtained by members of the Pulp and Paper Research staff at the Rothschild plant of Marathon Corporation. Many detailed measurements, tests, and tedious calculations were required, to say nothing of the physical labor involved in handling the pulpwood and securing samples. The author wishes to express his appreciation to all those whose efforts have made this report possible.

Testing and the Statistician

J. B. CATLIN

This paper discusses the use of statistical methods for improving measurements made by technical control men in the paper industry. While it teaches no statistics and avoids statistical language, it does attempt to give paper technologists a better insight into the statistical portions of their measurement problems. It provides some inkling into the statisticians approach to the solution of these problems, and also attempts to arouse the interest of technical men in the industry so they will make more serious efforts to incorporate modern statistics in their operations. The subjects discussed are: (1) precision and accuracy, (2) scales and significant figures, (3) new tests and improving present ones, (4) significance of measurement, (5) indirect measurement, (6) attributes, and (7) judgment measurement. The paper concludes that statistical methods make a very important contribution to the paper industry and will someday take their place beside the methods of chemistry, physics and the engineering sciences which are now used in technical control.

THIS PAPER is directed at technical men in the paper industry who are primarily concerned with the operation of control laboratories and testing stations.

Testing, as it is thought of in the paper industry is generally considered to consist of chemical and physical measurements of more or less complexity and elegance made under closely controlled conditions. For the purpose of this paper this definition is too limiting. It is proposed to discuss several kinds of measurements useful for technical control which could and should be made in routine laboratories and testing stations, some of which are made possible by statistical methods alone. While it is intended to discuss a variety of ordinary measurement problems, no time will be spent on the more basic ones of why the measurements are made. In technical control work in the industry scientfic measurements are made for only two basic purposes, i.e., control and inspection. There are a host of problems both technical and statistical connected with the design and operation of, for example, a really good process control system for basis weight. The procedure for measuring the sample basis weight is an integral part of the whole system of basis weight control, but may well be the least important part of the control scheme. By definition then, this paper is limited to measurement problems alone. Its purpose is to outline the contributions of statistical methods to improving measurements for technical control in the paper industry.

Before starting it should be mentioned that no prior knowledge of statistics is needed to read and understand this article. Like chemistry, physics, or the engineering sciences, mathematical statistics must be learned the hard way. There is no gold spoon short cut. The author hopes to, however: (1) point out the statistical parts of measurement problems, (2) give some insight into the basic approach, idea, or concepts the statistician uses in solving them, and (3) indicate the important gains to be made in operations by adding statistics to the chemical, physical, and engineering tools that are used in the operation of a mill.

J. B. CATLIN, Member TAPPI; Asst. Technical Director, Kimberly-Clark Corp., Neenah, Wis.

PRECISION AND ACCURACY

Perhaps the most important and at the same time the simplest contribution of statistics has to do with precision and accuracy. Yet it is surprising how widespread is the misunderstanding of these ideas. Experienced technical men have been asked how they defined precision and accuracy. A large proportion either didn't appreciate the difference or actually misunderstood them. One technical director said, "there isn't any difference." Actually, the adjustment of precision and the detection and control of inaccuracy is the "bread and butter" of all technical control men.

The time worn illustration of the marksman and his target is still the best way of explaining the difference between precision and accuracy. Two riflemen are shooting at the same target. One is shooting black bullets, the other white. Reference to Fig. 1a indicates that while both men centered their shots about the bull's eye the pattern of white's bullets has considerably greater spread than black's. The statistician simply portrays this situation with the two distribution curves shown, one having greater spread than the other, but both centered on the same mean or average. One pattern is said to have better precision (i.e., smaller spread) than the other. Reproducibility as it is sometimes understood in industry is synonomous with precision. In another rifle match the same marksmen produce patterns as shown in Fig. 1b. Here the spread is about the same but white's shots are not centered on the bull's eye. The statistician describes this experience with two distribution curves having the same spread or precision but differing averages or means. The displacement of white's shot from the bull (true mean) is called a constant error, inaccuracy, or bias. The sum of variabilities caused by precision and inaccuracy is sometimes called the errors of measurement.

It can be shown that for technical control work any inaccuracy is highly undesirable and cannot be tolerated. On the other hand, zero precision in any measurement is physically impossible. In fact small precision in many instances is both unnecessary and uneconomical. When is an observed measurement variation, which is always present, caused by unavoidable errors of precision, and when is it caused by a constant error or inaccuracy which must be hunted down and corrected? Here is one place where the statistician goes to work (*1*) to indicate what is being done and where the inaccuracy troubles are.

Have you ever had an operator, especially a technically trained one, say, "Quit arguing with me; you can't measure that close?" If some unavoidable variability (precision) in measurements must be accepted then how much is enough? The statistician can provide rigorous and elegant solutions to this question for each and every kind of measurement. A good rule of thumb is that the variation of a single test (expressed as variance) due to the measuring process shall fall in the range of 10 to 20% of the total

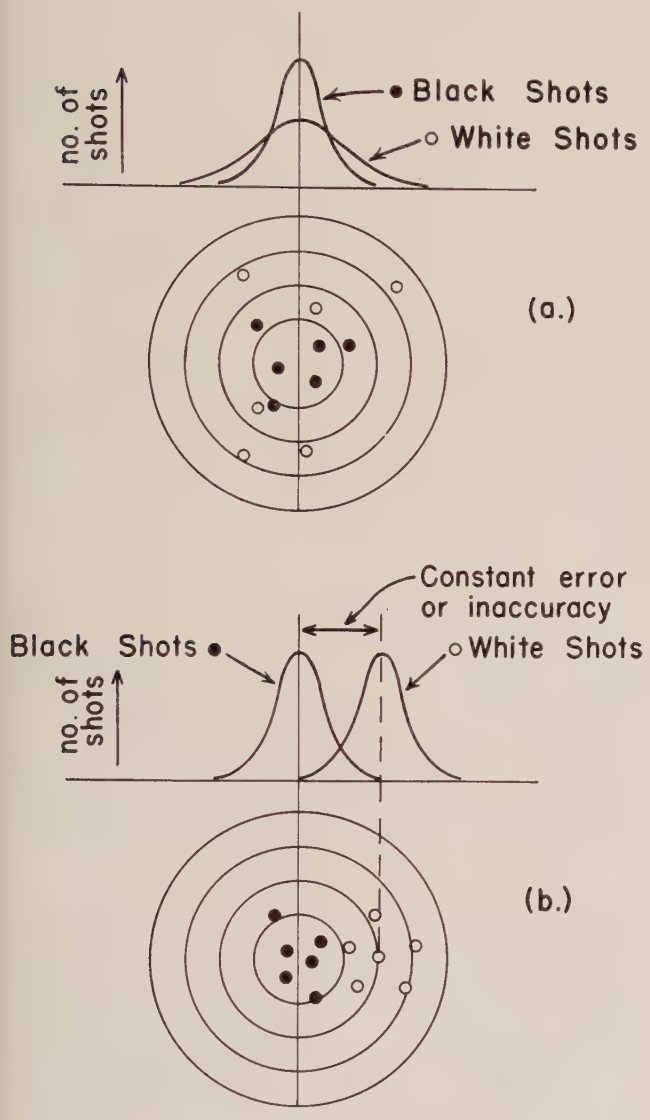

Fig. 1

variance which is the sum of the measurement variation (precision) plus the inherent variation of the process or material being measured. Many test methods in the paper industry are far too precise (so-called exact procedures). The statistician can show that nothing of practical value for either control or inspection is gained by using unnecessarily precise tests and a lot of money is wasted. In many cases it would be much wiser for the same money to make a larger number of less precise measurements or perhaps different tests. On the other hand, how can really small differences be measured with admittedly less than perfect procedures? Again, the statistician can indicate how many tests of what precision under what conditions must be made to most certainly detect a difference as small as the one being sought.

SCALES AND SIGNIFICANT FIGURES

There are many testing instruments of one kind or another with a bewildering variety of scales in the paper industry. If they are read too coarsely some information may be lost and the precision of the measurements impaired. If they are read too finely measuring productivity is reduced and additional calculation burden is imposed on the testers. Again there are rigorous statistical answers to these questions. The accepted rule-of-thumb is that the scale should be read so that the total variation (expressed as the range of single numbers) of the process or product being measured plus testing error (say an hour's production or one roll) can be divided into eight parts. If the scale is read coarser than this, a bias is introduced in estimating true values and small sample means are no longer normally distributed which causes later errors in interpretation of the data. If the scale is read more finely, no additional information useful for control or inspection is obtained and the added effort is wasted.

Two grades of 50-pound paper made on different machines were examined to get estimates of within hour variability for the purpose of basis weight process control in the machine direction. The distribution curves (a) and (b) in Fig. 2 show the estimated variation in single determinations. What should the paper mill testers be told about reading the basis weight scale? In the case of the (a) paper the range is from 47 to 53 pounds. The calculation then is:

$$\frac{53-47}{8} = \frac{6}{8} = 0.75$$

and since its scale happens to have 0.1-pound divisions, it's probably best to read it to the nearest 0.50 pound. With the (b) paper the range is 44 to 56 pounds. The calculation then is:

$$\frac{56-44}{8} = \frac{12}{8} = 1.50$$

and reading the scale to the closest 1.00-pound is plenty close.

It is sometimes useful to superimpose a scale over the original one. Then it is possible to use odd cell divisions like 1.33 pound etc. In this connection there is another simple, yet very useful statistical trick to reduce the burden of reading scales, entering logs, calculation, and posting on control charts where they are used. This technique is called the "transformation of scales." Continuing with the example in Fig. 2b put a new scale on the basis weight instrument showing 50 to 51 as +1, 51 to 52 as +2, etc. Do the same, going down from 50, except use —1, —2, etc. Now the tester reads only a single digit number for each measurement. A series of such numbers such as —2, +1, +4, and —1 are easily added algebraically by ordinary testers. The total instead of the average can

then be put on a control chart where zero is 50 pounds. Thus the calculation of the average is eliminated.

The statistician has something useful to say about the perennial problem of the number of significant places to carry forward in the arithmetic of a quantitative analysis calculation. As far as the problem of how finely to read the analytical balance is concerned, enough has been said to prevent the usual error of "putting a micrometer on the end of a hemp rope to

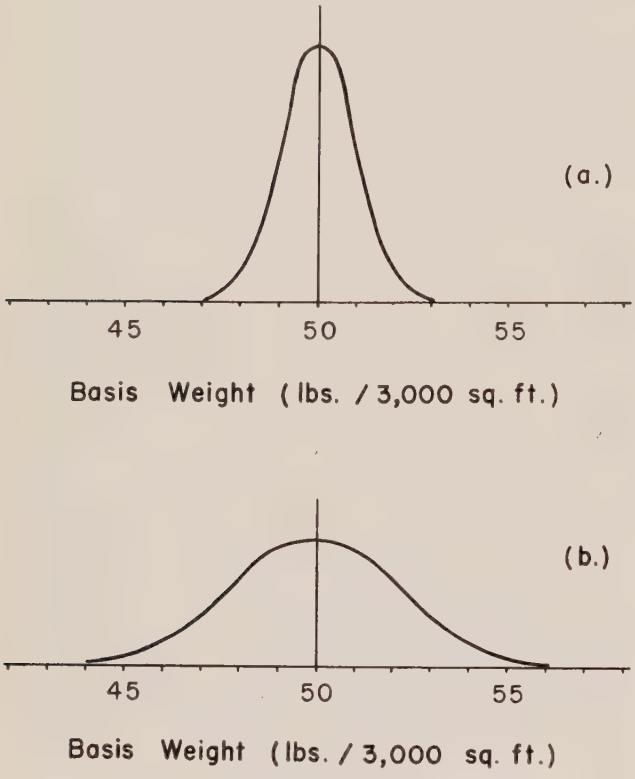

Fig. 2

measure a fog bank." A little reflection will make it apparent that the problem of "how many places" is solved by the rule of dividing the total range into eight parts. Some cut and try for each class of quantitative analysis (i.e., process or material classification) will quickly adjust the calculation to the optimum.

NEW TESTS AND IMPROVING PRESENT ONES

Many have struggled with the too frequent problems of developing new tests or improving present ones. The many technical problems of significance, productivity, cost, availability of apparatus, etc. will be omitted for the purpose of this part of the discussion. Reference should be made to the kind of scale it is desired to use (*2*). If it is intended to calculate even simple statistics such as the average or range, a linear scale is required. Space does not permit elaboration on this point. The criteria for obtaining the proper size of scale interval as well as adjusting for the optimum precision of measurement has already been discussed.

Recently a new bench instrument for measuring the ultimate tensile strength of tissue using the latest principles of pneumatic instrument engineering was developed. The new instrument is a beauty—simple, rugged, cheap, and easy to operate. It is, however, very sensitive and detects many differences near the ultimate tensile strength which were damped out by the old one. This reduces the working precision of the instrument for practical purposes requiring a considerably larger number of tests to detect a specified shift in strength with a desired probability. This example is mentioned to emphasize the importance of keeping clearly in mind the final use to which the test or instrument is to be put.

A typical problem in improving present tests is exemplified by the measurement of pulp strength which requires making several hand sheets from each pulp sample and then testing each sheet for bursting strength. How many sheets? How many tests on each sheet? The statistician can distribute the total cost of the test within and between the pulp sheets (using the analysis of variance) so that the desired precision can be obtained with minimum cost. In a complex test procedure such as pulp strength determination the measuring process really consists of a number of sub-processes, each of which adds its bit to the total precision. The statisician, can tear apart the whole process to indicate where the major sources of variability are and when they have been reduced by altering procedure or apparatus.

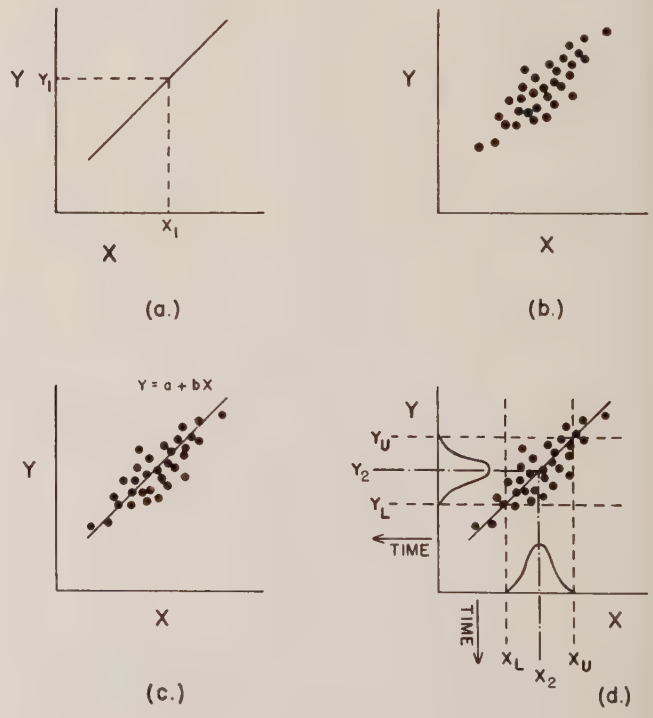

Fig. 3

One of the most important characteristics of new tests as well as one of the greatest weaknesses of existing procedures is accuracy. Where a number of testers are working with the same instrument or where several supposedly identical instruments are

employed the statistician will cause surprise and probably alarm by describing the frequency and magnitude of the inaccuracies in present testing procedures. This problem is adequately dealt with elsewhere (*1*).

SIGNIFICANCE OF MEASUREMENT

What do measurements mean? How well do they predict other measurements? Do they predict customer's experience? In asking these questions the author is obviously getting far afield from the original purpose of this paper. Much has been written; many problems remain. He can only touch lightly here on some of the more obvious contributions of statistical methods in this area.

Significance and relationship are synonomous for this purpose. The statistical concept of relationship is a tremendous improvement over the algebraic one. The statistician provides for chance variation whereas the mathematician can only cope with that part of the variation which seems to have a reason or cause. Thus the mathematician classically portrays simple relationship as shown in Fig. 3a and says that when the formula for the relationship between Y and X is known, knowledge of X_1 permits accurate prediction of Y_1. Many have been confused on this approach. Most of the time in the paper industry both Y and X are subject to random variation, i.e., errors of measurement and inherent variation in process or material. Thus if related paired data are plotted on a simple scatter chart they may look more like Fig. 3b and no nice simple line is apparent. The statistician can make a lot of sense out of the fly specks in 3b. He can select a line of best fit (3c) from the data and calculate the formula for the relationship if one exists. If pressed (and assuming a stable relationship does exist) he can describe the amount of residual variation in both Y and X as shown by the distribution curves in 3d; so one can say something like this to the operators, "control X between X_u and X_l then Y will stay between Y_u and Y_l."

In practical process work many simultaneous measurements are generally made and usually a mass of data is obtained which is impossible to analyze and interpret. The statistician brings some very powerful tools to bear on this type of problem. The analysis of variance and co-variance (*3, 4*) as well as multiple and partial correlation (*3, 4*) techniques contribute enormously to understanding the significance of the measurements. When process experiments are designed around the statistical models used for analyses, the experiments themselves are greatly improved.

There is a more frequent demand to make more elegant measurements in the fields of process experiment, field trials, clinical studies, and consumer product testing. These are all subjects in themselves and space only permits mentioning them here. The statistician is almost indispensible if much money for making these measurements is being spent.

INDIRECT MEASUREMENTS

W. A. Shewhart has classified (*5*) all product quality measurements as follows: type I inherent characteristic of product without relationship to anything such as weight, thickness, etc.; type II indirect measurements which are made to predict some final performance characteristic of the product; and type III direct measurement of final performance characteristic. A large proportion of the measurements made in the paper mill are in the type II class. Finish or smoothness is measured and an attempt is made to predict printability. Brightness is measured and an attempt is made to predict apparent whiteness. Or in process, viscosity is measured and an attempt is made to predict stock consistency. Because of difficulties with sampling, destructive testing, or inability to devise a type III test laboratories, testing stations, and mills are decorated with instruments making type II measurements. The trend in instrument engineering is definitely in this direction.

Most technical men know by sad experience the limitations of indirect measurements. They operate

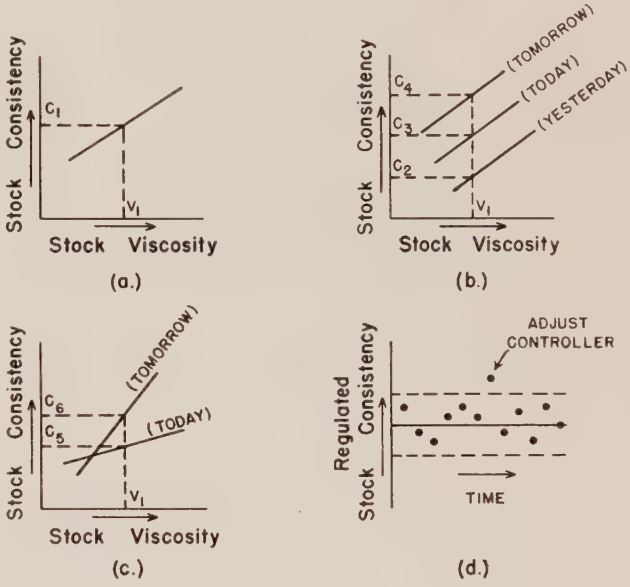

Fig. 4

on the theory that a real and stable relationship exists between the known and unknown variables. Thus in Fig. 4a their theory assumes that if V_1 is known, the consistency is C_1. For the purpose of this discussion the complications introduced by errors of measurement will be neglected. Under actual process conditions stock viscosity can and does vary at times independently from consistency. At least two kinds of relationship instability can exist. Figure 4b where only the intercept is changing in time and Figure 4c where both intercept and slope change. It is obvious under these conditions that any viscosity value V_1 is associated with a variety of consistencies $C_2 \ldots C_6$. Thus, there may be times when a consistency controller operating on the principle of indirect measurement may do more harm than good. There is no implication that consistency controllers are useless and a return to hand control is desirable, but it is definitely believed that all in-

direct measurements (particularly important automatic controlling ones) should be continuously audited by sampling-testing methods so that changes in relationship (i.e., calibration) are detected and corrected as they occur. Here the statistician comes to aid again. He can tell very elegantly just when and how much change in equation parameters (slope and intercept) occurs using routine test data. Or, in the case of this example, he can tell very simply when to change the adjustment arm on the consistency regulator to maintain the desired regulated consistency (Fig. 4d).

ATTRIBUTES

Most mill measurements are made with instruments having continuous linear scales. There is another class of measurements (*6*) which the operators and customers were making long before the technical men appeared on the scene. The statistician calls measurements made with instruments "variables" and those made by the naked eye "attributes." Some examples of attributes: the presence or absence in rolls of slime spots, calender cuts, hair cuts, or poor

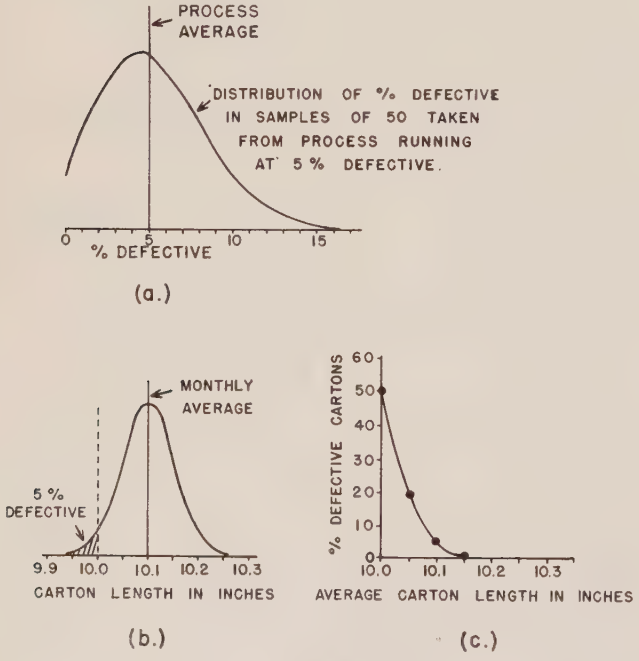

Fig. 5

starts, or in sheets of half sheets, folded corners, torn sheets, dirty paper, etc. When a specimen contains one of the attributes listed, it is called defective. If 100 sheets are examined and 10 are found defective, the sample is said to be 10% defective. The list can go on and on, depending on the refinement desired and ranging from raw material to final converted finished product. For years operators have insisted on decorating the test logs with these attributes measurements. They have been considered to be unscientific perhaps because their importance was not appreciated or it was not known how to handle them.

Much time will not be devoted here on their importance except to indicate they are a very important part of the quality of any product which in many instances can be measured by no other technique. For instance, there is plenty of evidence to indicate that the mechanical performance of paper on modern high-speed printing presses is strongly influenced by the presence of attributes defects at any general level of such physical properties as tear, tensile, or stretch.

Attributes measurements are easily made. No fancy apparatus or instruments are required. For this reason most customer complaints are in attributes. However, to avoid serious inaccuracies attributes must be carefully defined with words, samples, or, pictures. Testers must also be well trained and a continuous audit on their accuracy is essential (*1*).

Suppose 50 finished representative cases of paper are examined in a week and 5 of them have case nails puncturing some paper. The sample then contains $5/50 \times 100 = 10\%$ defective cases for protruding nails. Suppose the mill made 3500 cases that week. How many defective cases were actually shipped? Here the statistician steps in. If this week's data are all that are available, he can't help much. But if data have been collected for a number of weeks, he can tell whether or not the week's production in question is different from the others. Assume that analysis of past data indicates the process level for this attribute is 5% defective. The statistician can construct a distribution curve (Fig. 5a) showing how much variation of per cent defective can be expected in samples of 50 each. In this example a value as large as 10% can be expected quite frequently and the statistician would advise that there is no need to be excited about this one week's result.

In addition to "per cent defective" there is another attributes scale which is extremely useful, viz.: "number of defects per unit." Examples of this kind of attribute are: number of dirt specks of a given size per unit area, number of holes per unit area, or number of defects of all kinds in a box of facial tissue. The statistician possesses mathematical models describing the distribution of this statistic. He can tell how to sample and interpret the data. A moment's reflection is all that's required to emphasize the broad usefulness of this statistic in the paper industry.

In many cases attributes are related to variables and useful transformations can be made both ways. A folding carton for packaging sanitary napkins caused trouble on an automatic packaging machine when its long dimension was less than 10 inches. Samples from lots received for a month were measured with a rule and a distribution curve of the results constructed as in Fig. 5b. Five per cent of the cartons were found defective. It was cheaper to take less delays and waste on the packer and pay more for the cartons, so the average length was increased to 10.15 inches which reduced the per cent defective to less than 1%. Another way of showing the relationship in this example between attributes and variables is shown in Fig. 5c. Knowledge of this kind permits (among other things) adjustment of specifications to the economic optimum, in this ex-

ample minimizing the sum of the costs of defects and cost of oversize.

JUDGMENT MEASUREMENT

In spite of several generations of hard technical work in the paper industry it is still impossible to make significant scientific measurements in large areas of product quality. The researchers are constantly giving new and better measurements; ultimately they will close the gap and some day there will be instruments to measure everything. This will no doubt be a long time from now. Meanwhile mills must be run as well as possible. In those areas in which your operators are not supplied with reliable measurements they are proceeding daily with their best judgment to judge quality changes and take action on process or product. This activity constitutes a considerable part of the "art of papermaking."

The statistician is able to help make very considerable inroads into this art of judgment measurement to the great benefit of the operators and without expensive and time consuming research. It will be obvious that the whole technique of attributes measurement constitutes a very definite step in this direction. It also can be shown that some judgment measurements comprise in fact several attributes measurements, each of which have an unique weighting in the mind of the judge making the final judgment. For example, consider the evaluation of tissue for workmanship sometimes called formation. The operator measures by judgment the presence or absence of several attributes such as, holes, stock spots, crush marks, couch lines, streaks, etc., weights them together in his mind and decides whether or not one sheet is better than another. The statistician can determine which attributes skilled operators are using (*7, 8*) and how important each is in determining his final judgment (*9, 10*). He makes it possible to reduce a complex judgment to simple attributes which any tester can measure and put these together in a weighted equation which yields a single quality number or judgment index more closely predicting the combined judgment of a group of skilled operators than any individual operator is able to predict their combined judgment. This powerful technique makes possible the use of the best operator judgment at all levels in an organization without an enormous amount of quality training. It should also be added that the statistician can do the same thing for variables measurements. If a "sight and handling" judgment measurement includes variables such as brightness, dirt, finish, smoothness, stiffness, etc., he can tell how to combine them best for predicting customer's reaction.

So far the author has discussed relating attributes or variables measurements to judgment and in effect substituting objective for subjective measurement. There is always interest in eliminating judgment when possible because of its poorer precision and accuracy. Judges differ in their judgment. The same judge doesn't always get the same answer. These known errors have always flabbergasted technical men (not knowing how to cope with them) so there has been a tendency to neglect and reject judgment as a practical measurement. However, the statistician merely thinks of a series of judgment measurements as a distribution curve, having perhaps a broader spread than one derived from instrument measurement. He is able to work with them, improve their precision where desirable, and control their accuracy. Where operators are forced to rely on judgment alone (e.g., how soft or harsh is facial tissue), the statistician can help sort out the good from the bad judges, train new ones, and keep the good ones good (*7, 8, 9, 10*). Sometimes simply amazing things are uncovered when his methods are put to work. By showing how to use jury and panel techniques developed in other industries (tea, coffee, liquor, and dairy products) he can help improve the precision of judgment measurements so they detect small differences reliably and in fact rival the precision of instruments (*11*).

CONCLUSION

It is appreciated that the author has skipped lightly over this subject, presented far from exhaustive and convincing arguments, made some pretty sweeping claims for the power of statistical methods, and perhaps has caused some mental confusion. However, all of the techniques mentioned (and many more) have been put to work in the paper industry with good results. It is believed that statistical methods have a real place along side those of chemistry, physics, and the engineering sciences in improving the effectiveness and efficiency of technical control in the paper industry. The rate at which statistical methods will be put to work depends on the technical man.

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The Sulphonation and Delignification of Wood By the Sulphite Process

HOLGER ERDTMAN

When wood is heated with bisulphite cooking acid there is sulphonation of the lignin with the formation of a "solid" insoluble lignosulphonic acid. This acts as a cation exchanger and removes the calcium ions from the cooking liquor which becomes acidic. The sulphite process then enters the second phase characterized by the conversion of the "solid" lignosulphonic acid into soluble forms. The chemistry of the mechanism is discussed.

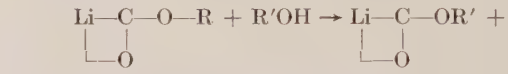
THE MOST complete chemical theory of the sulphite process, undoubtedly, has been advanced by Erik Hägglund of the Swedish Wood Research Institute, Stockholm, and much of what I have to say is the result of his work or of work initiated by him. Many of the conclusions are the result of numerous personal discussions with Hägglund and with Bror Holmberg and other Swedish colleagues. I cannot, therefore, claim to speak about my own views on this problem. I would merely like to indicate the Swedish outlook on lignin and lignin sulphonation and to mention some of the roads along which we are at present working.

Wood is a delicately organized, nonhomogeneous tissue, containing the main components: cellulose, the so-called hemicelluloses, and lignin, either in a free state or chemically combined. By means of a micromanipulator, Bailey, in 1936, isolated middle lamella and cell walls of Douglas fir and analyzed them separately. The middle lamella were found to contain far more lignin (about 70%) than the cell walls.

Recently P. Lange, of the Swedish Wood Research Institute, employing microspectrographic methods worked out by T. Caspersson, was able to confirm these results and also to prove conclusively that lignin occurs in wood in the state of an aromatic compound containing one aromatic nucleus per methoxyl group. During the sulphite cook, the pulping liquor first attacks this middle lamella and then the lignin which is deposited within the cell walls.

When heated with bisulphite cooking acid, the ash content of the wood material increases rapidly. Hägglund has shown that this is the result of a sulphonation of the lignin with the formation of a "solid," insoluble lignosulphonic acid. The sulphonated wood acts as a cation exchanger of the sulphonic acid type now so familiar to us all. In those days, however, this idea appeared very strange. The solid sulphonic acid withdraws calcium ions from the cooking liquor which consequently becomes increasingly acidic. The sulphite process now enters into its second phase, characterized by the conversion of the "solid" lignosulphonic acid into soluble lignosulphonic acids which may be isolated in various ways from the waste liquor.

A reaction of great importance for the understanding of the delignification process was discovered by Kullgren. Strong sulphite pulp which still contained solid lignosulphonic acids—as calcium salts—was successively washed with hydrochloric acid and distilled water to remove all calcium ions. This material was then heated with water or alcohol to about 80 to 100° at which time the solid sulphonic acid slowly passed into solution. The mechanism of this reaction is obviously a hydrolysis of an acetal linkage. The "carbonyl" function must be situated in the lignin molecule, since Kullgren found that the lignin product obtained with alcohol contained more alkoxyl groups than that obtained with water. Thus we can write:



Hägglund has studied the formation of solid lignosulphonic acids very extensively. This reaction occurs more quickly in an acid solution than in a neutral one and will take place also, but more slowly, in a weakly alkaline solution. In alkaline or neutral solution, the sulphur content of the sulphonated wood will remain low. In more acidic solutions, a more sulphur-rich solid lignosulphonic acid is obtained. As soon as the sulphur content amounts to about one sulphur atom per two methoxyl groups, however, the lignosulphonic acid passes into solution. This is the normal sulphur content of lignosulphonic acids isolated from waste liquors.

By heating wood with a strong solution of sodium sulphite alone or mixed with bisulphite, one is able to obtain a sulphonated wood without too great a loss of lignin as a result of the formation of soluble lignosulphonic acids. A large proportion of these soluble lignosulphonic acids obviously has a rather low molecular weight. They are only partly precipitated by organic bases such as strychnine. They are absorbed by ordinary anion exchangers and dialyzable. The sulphonated wood, when subjected to the Kullgren process, furnishes large amounts of soluble lignosulphonic acids. The sulphur content, always less than one sulphur atom per two methoxyl groups, varies considerably because of the sulphur content of the sulphonated wood and the time of heating with water. Lignosulphonic acids prepared in this way have proved to be almost ideal starting materials for the study of lignin sulphonation, lignin spec-

HOLGER ERDTMAN, Royal Institute of Technology, Department of Organic Chemistry, Stockholm, Sweden.

troscopy, and lignin constitution. These lignosulphonic acids have high molecular weights. They are precipitated by organic bases—e.g., bis-*N*-dimethylaminodiphenylmethane or strychnine. They pass through anion exchangers and are nondialyzable.

A typical composition of a lignosulphonic acid obtained in this way is the following:

(*A*) $C_9H_{6.4}O_{0.96}(OCH_3)_{0.84}(SO_3H)_{0.29}(OH)_{1.20}$.
$\Sigma OH + SO_3H = 1.49$; $S/OCH_3 = 1/3.25$; or
$C_9H_{8.83}O_{3.39}$, if OCH_3 and SO_3H = OH.

The preparation reduces Fehling solution only very slightly, either before or after hydrolysis with hydrochloric acid. This shows that the number of aldehydic carbonyl groups is low. The linkages cleaved when this sulphonic acid material was liberated from the original solid lignosulphonic acid, therefore, probably were of a keto acetal type.

When this lignosulphonic acid (*A*) was subjected to a short sulphite cooking employing ordinary sulphite cooking acid, the resulting acid (*B*) had the following composition:

(*B*) $C_9H_{6.3}O_{0.82}(OCH_3)_{0.96}(SO_3H)_{0.42}(OH)_{0.99}$.
$\Sigma OH + SO_3H = 1.41$; $S/OCH_3 = 1/2.28$; or
$C_9H_{8.7}O_{3.19}$, if OCH_3 and SO_3H = OH.

When sulphonic acid *A* was subjected to a sulphite cook of longer duration, the sulphonic acid preparation (*C*) was obtained.

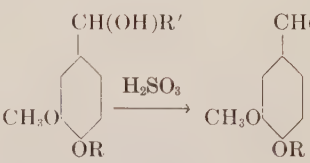
(*C*) $C_9H_7O_{0.91}(OCH_3)_{0.94}(SO_3H)_{0.71}(OH)_{0.84}$.
$\Sigma OH + SO_3H = 1.55$; $S/OCH_3 = 1/1.32$; or
$C_9H_{9.5}O_{3.50}$, if OCH_3 and SO_3H = OH.

Thus, these sulphur-poor lignosulphonic acids may be sulphonated far above the stage reached in normal sulphite cooking. It is probable that, under ordinary cooking conditions, some water is eliminated from the lignin molecules with the formation of double bonds conjugated with the aromatic nucleus (there are at least strong spectrographic indications for this). The preparations contain more oxygen than Freudenberg's cuproxam lignin, indicating that lignin may contain one hydroxyl group more per C_9 unit than is generally assumed on the basis of cuproxam lignin, or they may contain water which is difficult to remove in the ordinary drying operation. The low sulphonated lignosulphonic acid (*A*) contains more than one hydroxyl group per C_9 unit. The sum of hydroxyl and sulphonic acid groups remains rather constant in all preparations, indicating that the essential reaction which occurs during sulphonation is a substitution of a hydroxyl group for a sulphonic acid group. The ultraviolet absorption is not changed when *A* is sulphonated. The slight increase in the sum of hydroxyl and sulphonic acid groups when passing from acid *B* to acid *C* may, perhaps, indicate a somewhat different mechanism at the end of the sulphonation of lignin. However, we are dealing here with a supersulphonation of very little technical interest. The sulphonation reaction occurring during normal sulphite cooking is largely the result of substitution of hydroxyl groups.

The hydroxyl group estimations were carried out by acetylating pyridine salts of the different acids with acetic anhydride and pyridine and estimating the acetoxyl content of the resulting product. A full description of the technique employed will be published elsewhere.

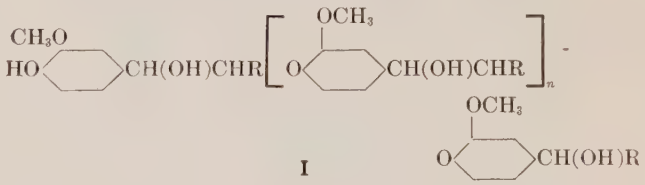
As the result of his very extensive studies on the reactions of thio acids (especially thioglycolic acid) with lignin and various other compounds, Holmberg suggested that the sulphonation of lignin essentially involves the substitution of hydroxyl groups of outstanding reactivity. Moreover, he found that *a*-phenethyl alcohol, $C_6H_5CH(OH)CH_3$, when heated with bisulphite cooking acid, was converted into the sulphonic acid, $C_6H_5CH(SO_3H)CH_3$. Thus, it appears possible that the reactivity of lignin toward bisulphite may be the result of the substitution of a hydroxyl group similarly situated in the lignin molecule. In the case of phenethyl alcohol, however, the speed of reaction was unsatisfactory and B. Lindgren, therefore, has subjected a series of more ligninlike substances of the same type to sulphite cooks with acids of varying acidity.

The substances have the following structure:



R = H or CH_3; R′ = H, CH_3, or C_2H_5.

All these compounds were sulphonated with a speed quite comparable with that of lignin, even at pH 5. Vanillyl alcohol (R = H; R′ = H) was sulphonated quite readily at pH 6.6. Veratryl alcohol (R = H; R′ = CH_3) failed to react at this pH.



I

At present, B. Leopold is engaged in the synthesis of a series of compounds of type I and various cyclic analogs. They also yield sulphonic acids. Lindgren's model substances show striking similarities to lignin. They may be heated in a dry state for 6 hours at 130° without suffering any change. In the presence of water or acids, however, they quickly undergo polycondensation with formation of amorphous products which cannot be sulphonated. Moreover, they react with phenols or anilines in exactly the same way as lignin. No doubt, they are the best model substances for lignin yet available.

It is very common in science that the study of abnormal processes provides the key to the deeper understanding of the normal process.

Pine heartwood cannot be properly pulped according to the normal sulphite process. Hägglund and others ultimately traced the cause back to a specific extractable heartwood constituent, now structurally elucidated and known under the name of pinosylvin (3,5-dihydroxy-*trans*-stilbene). It also functions as

a specific antibiotic, rendering the heartwood durable to decay and repellent to insects. Other nondigestible woods contain phenolic substances of the same type or belonging to quite different groups. Examples are flavones and flavanones contained in many pines and in Douglas fir, and tannins related to catechin in chestnut and quebracho wood. Under the acidic conditions of the normal sulphite cook, these phenols (or other reactive phenols artificially added—e.g., resorcinol or phloroglucinol) will condense with the lignin of the wood just as formaldehyde is condensed with phenols in the formation of bakelite. The lignin molecules will be linked together by small amounts of the phenol to form giant molecules which are completely insoluble. Quantities of pinosylvin as small as 0.2 to 1% will effectively block the delignification. This is illustrated in Fig. 1.

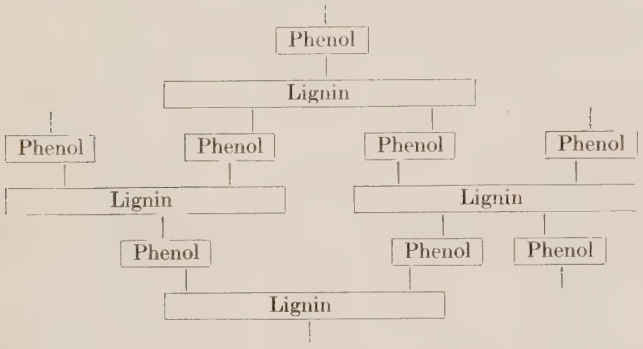


Fig. 1. Schematic representation of insoluble condensate

Pine heartwood can be pulped according to a two-step method devised by Graham in 1882. This involves pretreatment of the wood with sodium sulphite solution followed by normal acid sulphite cooking liquor.

Experiments have shown that the same result could be obtained when the pine heartwood was substituted by sprucewood impregnated with pinosylvin or other reactive phenols such as resorcinol. If sprucewood was presulphonated with sodium bisulphite and the resulting material subjected to a normal acid sulphite cook in the presence of resorcinol, a pulp of good quality was obtained and the phenol could be recovered unchanged from the waste liquor.

To explain these results, it is obviously necessary to assume that lignin contains groups of different reactivity. One type of group (*A*) reacts with sulphite in acid, neutral, or slightly alkaline solution but with phenols only in acid solution. Another type of group (*B*) reacts with sulphite in acid solution but is unreactive to phenols.

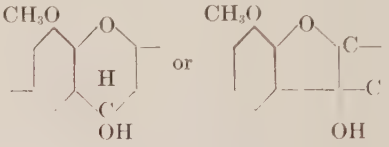
A— Lignin —*B*

In the presence of normal acid cooking liquor, therefore, group *A* will react with both sulphite and phenols; group *B* will become exclusively sulphonated.

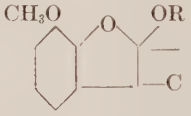
In the presence of sodium sulphite cooking liquor, group *A* will become sulphonated but not phenolated. Group *B* will remain unaffected. When the sulphite is removed and the cooking continued with acid cooking liquor, group *B* will become sulphonated but not phenolated and normal delignification takes place.

Obviously this theory of the occurrence of two groups of different reactivity is also capable of explaining the stepwise sulphonation-delignification in the normal sulphite process.

In the early stages of pulping, when the liquor still possesses a low acidity, group *A* will be preferentially sulphonated. This causes the formation of the solid, insoluble, lignosulphonic acid. In the later stages of the cook, when the pH drops, group *B* will become capable of reaction. As already mentioned, this is assumed to be caused by the hydrolysis of an acetal link. Group *B* is probably involved in the formation of this link. The main difference between groups *A* and *B*, therefore, may be that *A* occurs free in lignin, whereas *B* is involved in the structure of larger molecular complexes. With regard to the different reactivity of the groups to phenols, however, this assumption appears improbable. *A* and *B*, therefore, probably represent groups of different types. Group *A* can be interpreted as a hydroxyl group of the type occurring in benzyl alcohol—e.g.,



Group *B* may perhaps be interpreted as an acetal group—e.g.,



containing a "masked carbonyl group." The nature of R is not clear and very difficult to elucidate.

There are many arguments in favor of the view that lignin is linked to carbohydrates. In such a case, R is a carbohydrate. It cannot be denied, however, that R may be another lignin molecule and that, consequently, the main portion of the lignin of wood is a two- or three-dimensional macromolecule built up of smaller lignin chains, connected by acetal linkages, such as those assumed to occur in the sulphonic acids obtained from waste liquor.

It appears probable that the very lignin-rich "middle lamella" may contain lignin-lignin complexes. The lignin-poor cell walls, on the other hand, may contain lignin-carbohydrate complexes. However, even here, the smaller lignin molecules may be linked directly to each other, forming lignin layers or isolated lignin islands alternating with carbohydrates, or forming a lignin network penetrating the carbohydrates in all directions.

The final elucidation of the submicroscopic architecture of the middle lamella and the cell wall is, therefore, awaited with great interest. This problem is of great importance in relation to questions regarding the delignification of wood according to the sulphite and sulphate processes, the bleaching of pulp, and its reactivity to different chemicals.

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Titanium Pigments in Coating

WILLIAM R. WILLETS

The beneficial results of pigmenting typical paper coatings have again been demonstrated by the presentation of data not heretofore available in the literature. Such pigmentation results in improved brightness, color, and opacity, decreased show-through and better printability. About 2.5 parts of rutile titanium calcium pigment are equivalent to 1 part of anatase titanium dioxide in producing such improvements. The rutile titanium calcium pigment has been shown to be considerably more effective than titanium barium pigment (the manufacture of which has been discontinued). Pigmentation of typical coating mixes did not alter their rheological properties. The gloss obtained with pigmented coatings on calendering was at least as good as the gloss obtained with unpigmented coatings. The cost of pigmentation of printing papers will depend on the final basis weight of such papers, the amount of coating applied, and the extent of pigmentation, but will vary from about $2.00 to $8.00 a ton. In the case of coated paperboards the cost will also vary with the weight of the board, the amount of coating applied and the extent of pigmentation from about $1.00 to $3.00 a ton. The rutile titanium calcium pigment offers definite economic advantages over titanium barium pigment, and some advantage over titanium dioxide.

TITANIUM pigments have long been used in the coated paper industry and as a matter of fact the first reference to such use was made over 20 years ago (*1*). However, while the literature on the beater addition of these pigments, dating back to 1933, is rather extensive there has been comparatively little reported regarding their use in paper coating (*2*). The TAPPI Monograph (*3*) published in 1948 helped to correct this deficiency but since its publication much additional work has been done and this paper will attempt to present the more significant results obtained.

In recent years the paper coating industry has shown almost phenomenal growth, especially in the field of paper machine coating, and the idea has been expressed more than once that eventually practically all paper will be coated. The ever-increasing production of coated publication and other printing papers, of coated opaque waxing stock, of coated paperboards, and of a multitude of coated specialties certainly lends credence to this opinion.

Since many of the new developments involve the use of lighter-weight coatings applied to base stocks of low brightness and opacity, the role of titanium pigments takes on added significance because of their unusually great brightening and opacifying characteristics. Since titanium pigments increase both the opacity (covering power) and brightness of a coating, it is natural that they will improve these characteristics in the final coated paper.

WILLIAM R. WILLETS, Member TAPPI; Chairman Pigments Subcommittee, TAPPI Coating Committee; Technical Service Laboratories, Titanium Pigment Corp., New York, N. Y.

TITANIUM PIGMENTS

One significant change in the titanium pigment picture has recently taken place, namely the discontinuance of the manufacture of the titanium barium pigment. While the anatase form of titanium dioxide has been the opaque pigment most favored, not only for beater addition but for paper coating as well, the barium extended product also found wide usage. The nonavailability of the titanium barium pigment (composed of 30% anatase titanium dioxide and 70% barium sulphate) has resulted in great interest in the rutile titanium calcium pigment (composed of 30% rutile titanium dioxide and 70% calcium sulphate anhydrite), a product which because of its exceptionally high-hiding power and brightness has proved of

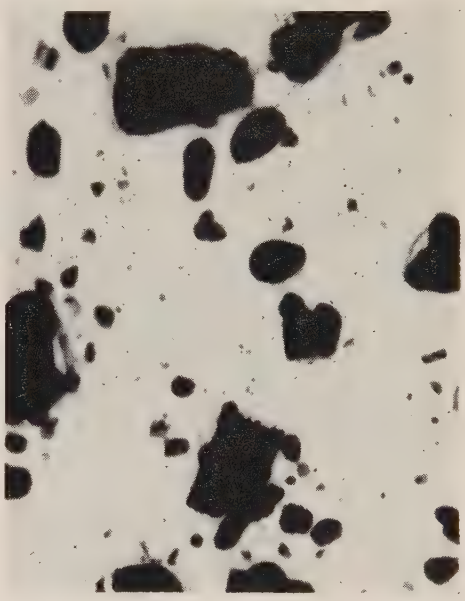

Fig. 1. Coalesced rutile titanium calcium pigment. Magnification 10,000×

definite value to the paper industry as well as to the paint industry which has been using it in ever-increasing amounts for a number of years. As a matter of fact, one of the main reasons for discontinuing the manufacture of the titanium barium pigment was the paint industry's gradual and eventually almost total substitution of the calcium base pigment for it.

The source, commercial preparation, and general properties of titanium pigments have already been described in the TAPPI Monograph referred to above (*3*) and additional details regarding the titanium calcium pigment have recently been published (*4*). However, it may be well to point out certain facts particularly germane to paper coating.

There are two main types of rutile titanium calcium pigment. In one the product is made by mechanically

mixing rutile titanium dioxide and calcium sulphate anhydrite. However, the type referred to in this article is a true coalesced composite secured by precipitating the titanium dioxide in the presence of the calcium sulphate anhydrite base. This coalescing is confirmed by electron micrographs. Figure 1 shows the particle of coalesced rutile titanium calcium pigment and Fig. 2 shows the effect of removing the calcium sulphate anhydrite by means of a solvent. The finely divided titanium dioxide can be seen to be arranged about the voids originally occupied by the calcium sulphate. In contrast, Fig. 3 shows the effect of a similar treatment with a mechanically mixed rutile titanium calcium pigment; here the structure of the titanium dioxide coating over the calcium sulphate does not appear. Figure 4 is an electron micrograph of anatase titanium dioxide.

Among other things these electron micrographs serve to indicate the small particle size of titanium pigments.

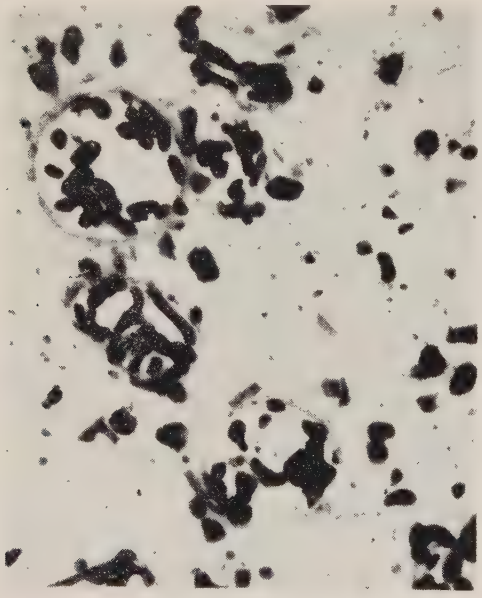

Fig. 2. Coalesced rutile titanium calcium pigment from which calcium has been removed by solvent. Magnification 10,000×

The average diameter of titanium dioxide particles is about 0.3 micron, and of rutile titanium calcium pigment 0.5 to 0.8 micron. Other pertinent data regarding titanium pigments have already been given (*3*) and need not be repeated here, although it may be well to note that of the products considered herein, the anatase titanium dioxide has the highest refractive index (2.55) followed by the rutile titanium calcium pigment (1.98) with titanium barium pigment the lowest (1.91). By contrast clay and calcium carbonate have a refractive index of 1.55 to 1.56, very close to that of cellulose and starch (1.52), and of paraffin wax (1.47).

The water dispersing types of titanium dioxide and titanium barium pigment frequently do not require the addition of any dispersing agent although much depends on the hardness and type of water used. Naturally, when they are used in conjunction with clay or calcium carbonate, dispersants are needed to aid the dispersion of these products. The water absorption of the water dispersing types of titanium pigments is very low and only 30 pounds or less of water are required to give liquid slurries with 100

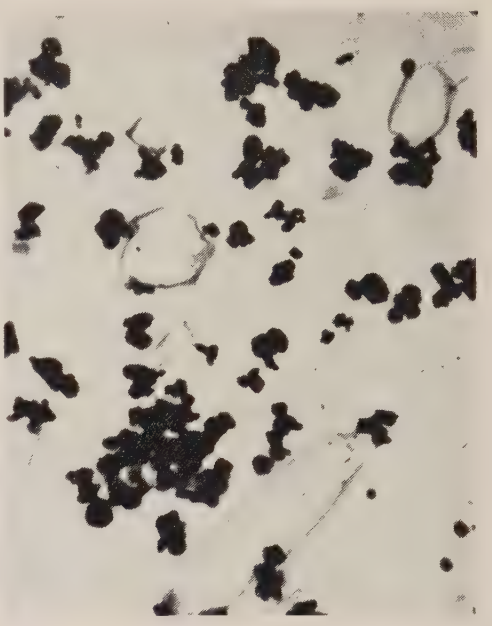

Fig. 3. Another type rutile titanium calcium pigment from which calcium sulfate has been removed by solvent. Magnification 10,000×

pounds of the pigment. This is important since it permits making water slurries with high-total solids content, of 75% or over.

The rutile titanium calcium pigment is not a true

Fig. 4. Titanium dioxide (anatase). Magnification 10,000×

water dispersing type, and if no dispersant is used it is difficult to obtain water slurries of over 45% total solids. Such slurries tend to be "puffy" and thixotropic. This difficulty can be overcome by dissolving

from 1.5 to 2.5% of gum arabic based on the pigment in the water used for making the slurry. If this is done, water slurries containing over 70% total solids can be readily made, and the slurries lose their "puffy" nature and become free flowing. Many other materials were tried to effect the same result among which might be mentioned the glassy phosphates (such as sodium hexametaphosphate and sodium tetraphosphate), sodium silicate, casein (cut with caustic soda, soda ash, borax, or ammonia), sodium phytate, polyvinyl alcohol, and carboxymethyl cellulose. While some of these aided to some degree in permitting an increase in total solids and reducing "puffiness," none was nearly as effective as gum arabic. Therefore, in making water slurries of rutile titanium calcium pigment, the use of gum arabic is recommended. Such use has proved very effective not only in the laboratory but in commercial practice as well.

Dow 512K latex and casein. Such coating mixes gave comparable viscosities to unpigmented mixes of corresponding types, and there was no appreciable change in the rheological properties upon agitation or standing for over 24 hours. Such coating mixes all involved the use of gum arabic as a dispersant for the rutile titanium calcium pigment, and also the use of sodium hexametaphosphate when clay or calcium carbonate formed a constituent of the mix.

In making up pigmented coating mixes, the pigment was added to the slurry water containing the dispersants as noted above, followed by the clay or calcium carbonate. After stirring until dispersion was obtained, the adhesive was added in solution. Since well dispersed, smooth homogeneous coatings can thus be obtained without actual "milling" (as for example in a ball mill) the indications are that simple agitation, such as is available in most coating mills, will usually

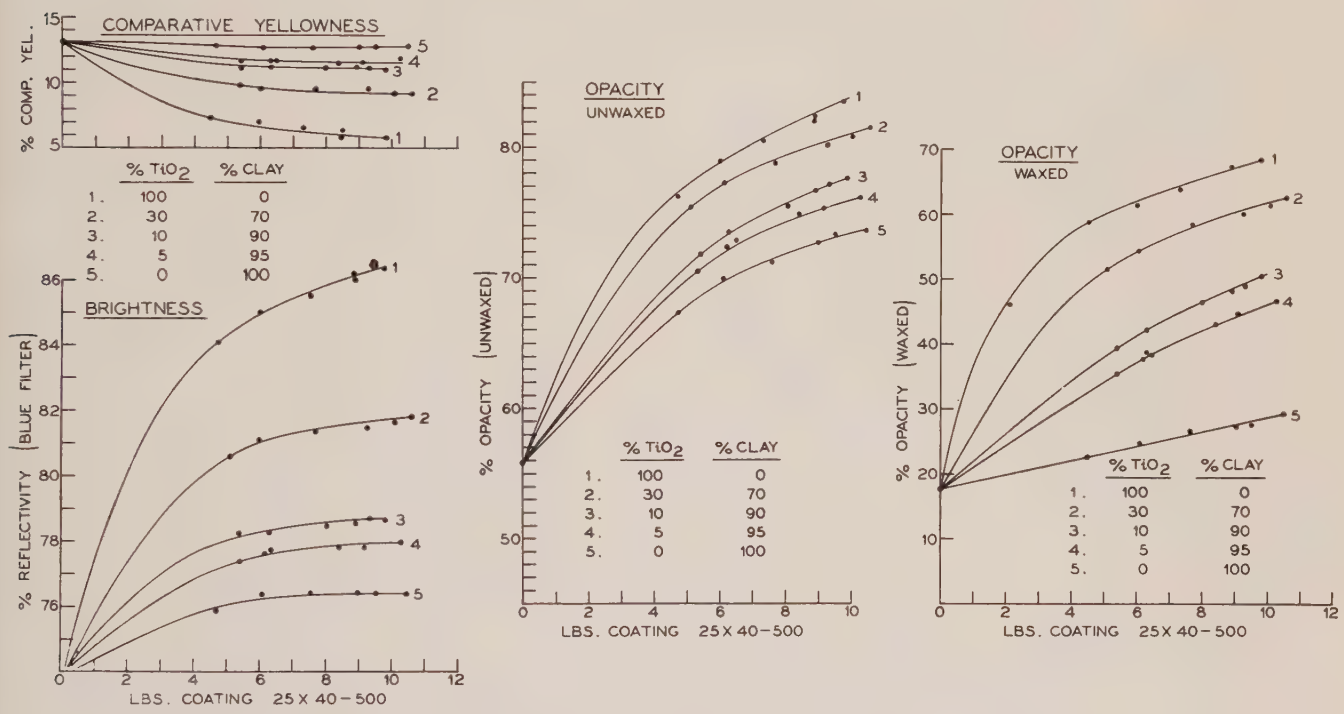

Fig. 5. Titanium dioxide-clay coatings on 25-pound raw stock. Starch adhesive

It might be incorrectly assumed that since the calcium sulphate anhydrite portion of the calcium base pigment is very slightly water-soluble difficulties might arise. However, it may be recalled that satin white, in which the calcium sulphate portion is far more soluble and reactive than is calcium sulphate anhydrite, has been used for coating paper for many years. There is also reason to believe that with coalesced rutile titanium calcium pigment solubility may be inhibited by the fact that the titanium dioxide tends to coat the calcium sulphate.

As a matter of fact, coating mixes of from 35 to over 60% total solids, using the rutile titanium calcium pigment alone and in admixture with clay, or clay and calcium carbonate, have been made with a wide variety of adhesives—starch, casein (cut by various means, caustic soda, soda ash, borax, or ammonia), soya protein, soya flour, and a mixture of

suffice although it is probably also true that in general a milling or grinding operation benefits any paper coating.

The above points have been made to indicate that the pigmentation of paper coatings with either titanium dioxide or rutile titanium calcium pigment does not involve procedures or equipment different from that now employed for unpigmented coatings. It is true, of course, that gum arabic (in the case of the calcium base pigment) may introduce a dispersant heretofore not commonly employed by coating mills, but it may also be said that the introduction of new dispersants and other auxiliary chemicals is not a novel experience to most producers of coated paper.

EXPERIMENTAL COATING STUDIES

The foregoing section has indicated that coatings containing titanium pigments should offer no difficul-

ties in preparation or application. Such conclusions have been substantiated not only experimentally but also in commercial practice.

In all the experiments noted, the coatings were prepared by simple mechanical agitation. The pigments were slurried in water in which the dispersants had been dissolved (gum arabic in the case of the rutile titanium calcium pigment and sodium hexametaphosphate in the case of clay and calcium carbonate) and after dispersion was complete the adhesive was added in solution. The clay used was a typical coating grade of Georgia kaolin while the calcium carbonate was a precipitated product. A dextrinized starch of medium viscosity was used as the adhesive in most of the experiments with an alkali-cut casein in others. All these are being widely sold to the paper coating industry and thus may be considered as entirely representative. The viscosity of all coatings was determined using the Stormer viscometer soon after

was only 12 inches so that the rewound paper could be handled on the experimental supercalender which only accommodates a 12-inch web. This three-roll supercalender (cotton middle roll and chilled top and bottom rolls) operates at about 60 f.p.m., the pressure being applied by means of independent pressure screws. It can be used either as a sheet calender or for calendering from rolls.

The weight of coating applied was determined after conditioning at 50% relative humidity, by weighing not less than 36 square feet of the coated paper and subtracting the weight of a corresponding area of raw stock, both weighings being made to the nearest 0.1 gram. The weights thus obtained were converted to "TAPPI basis," that is the weight of 500 sheets cut 25×40 inches. In all cases, six different weights of coating were applied so as to permit plotting the optical results versus coating weight. The effect of coating weight on optical properties is well known (*5*).

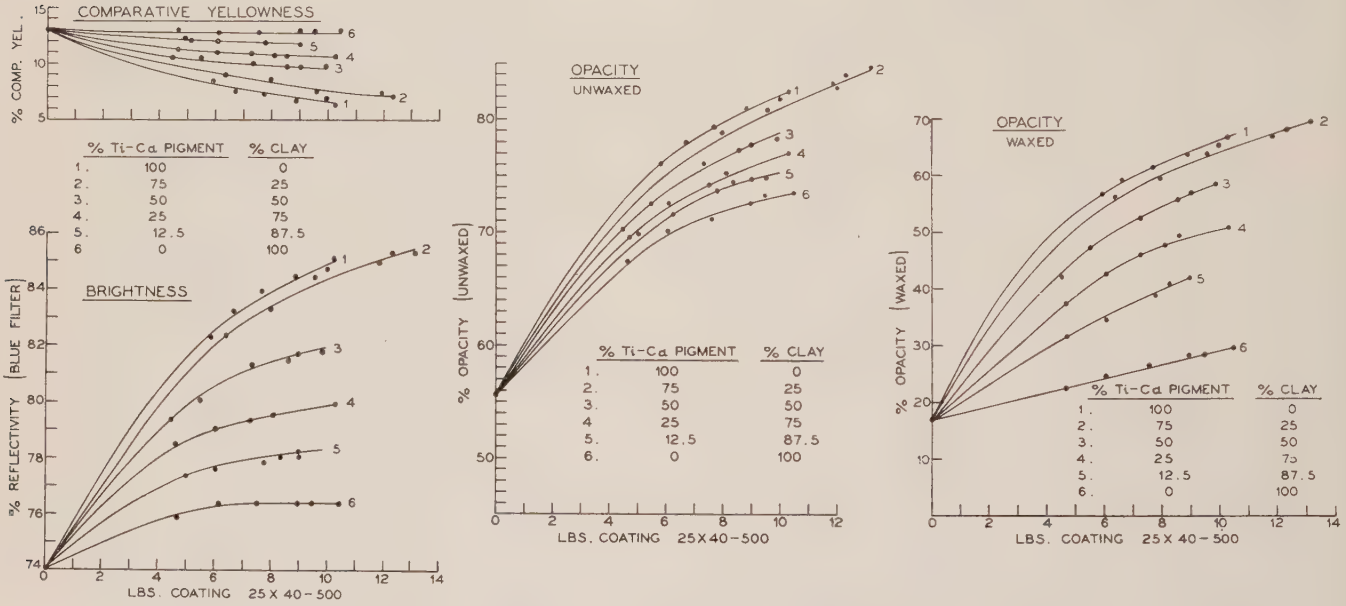

Fig. 6. Rutile titanium calcium-clay coatings on 25-pound raw stock. Starch adhesive

preparation and after 24 hours, and in some cases after 48 hours. The change in viscosity upon standing was negligible. In all cases the viscosity as measured on this instrument was about 61 Krebs-Stromer units, corresponding to an "apparent viscosity" of 325 centipoises. All the coatings were somewhat thixotropic but free-flowing and easily applied.

The paper was coated on an experimental coating machine designed on the doctor rod principle in which an excess of coating is fed to the sheet by means of a roll revolving in the coating pan, the excess being removed by means of wire wound rods, the coarseness of the wire-winding determining the weight of coating applied. The coated paper is then passed over heating units (included as an integral part of the machine) and rewound. The machine speed is rather slow, about 30 f.p.m., but at this slow speed, drying can be effected at temperatures below 220°F. While the coater can handle rolls up to 20 inches in width, the size used

The reflectivity of all samples was measured with the Hunter Multi-Purpose Reflectometer using blue, green, and amber filters. The reading with the blue filter approximates "TAPPI brightness." The comparative yellowness was calculated by dividing the difference between the amber and blue filter readings by the green filter reading and multiplying by 100. Opacity was measured before and after waxing using the Bausch and Lomb opacimeter. The samples were waxed by immersion in molten paraffin (138 to 140) for half an hour at 170°F. and then drained for a similar length of time at the same temperature.*

Selected samples of comparable coating weights were also printed on the Vandercook No. 4 proof

* The opacity resulting from such total impregnation is considerably less (usually 6 to 8 points) than that obtained by commercial waxing since in the latter case impregnation is less thorough because the paper is passed rapidly through the molten wax, through squeeze rolls and then through a refrigerating device to set the wax and give gloss. However, the laboratory method of complete impregnation does give indicatory and reproducible results.

press using the method reported by Berberich, et al. (*6*). Such printing tests gave qualitative indications of show-through which tended to be in line with the opacity after waxing, and also gave indications of printability as shown by the definition of halftone dots.

A number of series of tests was made to determine the effect of pigmentation on the properties noted above. In one series, the pigmentation was carried up to 100% for both titanium dioxide and rutile titanium calcium pigment. In these runs, a 25-pound, M.G. tissue was coated on the unglazed side and the paper then lightly calendered from rolls. The coatings, which were prepared as described above, had about 44% total solids, using an adhesive ratio of 25% starch.

The effect of pigmentation with titanium dioxide is shown in the curves of Fig. 5, and with rutile titanium calcium pigment in the curves of Fig. 6. Among other things these curves show the effect of coating weight on the various optical properties for any given coating mix, an effect that has already been reported (*5*). As pigmentation is increased, there is much less tend-

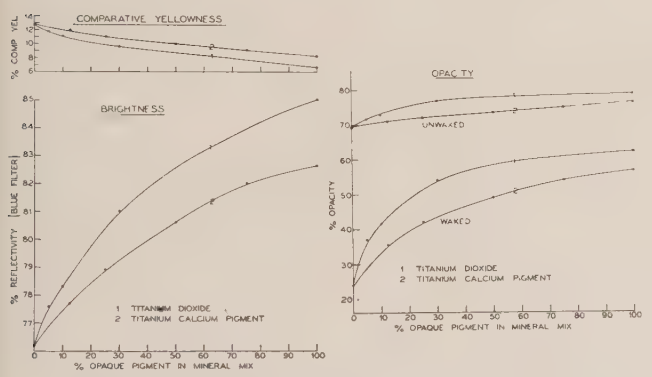

Fig. 7. Effect of pigmentation at 6 pounds coating on 25-pound raw stock. Starch adhesive

ency for the brightness and comparative yellowness curves to level out with increasing coating weight because of the higher ultimate brightness and covering power resulting from pigmentation. These curves also show that it is possible to get better brightness, color, and opacity with pigmented coatings at much lower coating weights than is possible with an unpigmented coating. The greatest improvement in optical properties is obtained at the lower pigmentations, that is, the improvement resulting from 5% pigmentation with titanium dioxide is greater than the difference between this pigmentation and a 10% pigmentation. At comparable coating weights, the pigmented coatings showed less show through and better printability as indicated by the clearer definition of the halftone dots. There seemed no difference in ink receptivity and drying rate between the pigmented and unpigmented coatings.

The effect of pigmentation at a constant coating weight of 6 pounds per ream, as derived from the foregoing curves, is shown in Fig. 7. (Plots at other coating weights would show essentially the same relationship.) These curves indicate that 2.5 parts of the rutile titanium calcium pigment are approximately equivalent to 1 part of titanium dioxide producing slightly better brightness and color and slightly less

Table I. Summary for 6-Pound Coating (from Curves)

	Reflectivity, % (blue filter)	*Comparative yellowness, %*	*Opacity, % Unwaxed*	*Waxed*
25% Starch-Pigment Ratio, Light Calendering				
All clay	76.2	12.8	69.5	24.0
5% TiO_2, 95% clay	77.6	11.8	71.8	37.0
10% TiO_2, 90% clay	78.3	11.3	72.8	41.5
12½% Titanium-calcium, 87½% clay	77.7	12.0	71.0	35.5
25% Titanium-calcium, 75% clay	78.9	11.0	72.0	42.0
(25-Lb. basis raw stock	74.0	13.0	55.6	17.5)
30% Starch-Pigment Ratio, Light Calendering				
All clay-calcium carbonate, 3:2	73.0	16.7	91.3	28.0
10% TiO_2, 90% clay-carbonate	74.5	14.7	92.8	46.6
25% Titanium-calcium, 75% clay-carbonate	74.8	14.2	92.5	46.0
(45-Lb. basis raw stock	67.0	21.3	88.8	21.4)
13% Casein-Pigment Ratio, Uncalendered				
All clay	74.1	15.0	91.3	30.8
10% TiO_2, 90% clay	77.0	12.2	92.5	49.0
25% Titanium-calcium, 75% clay	77.9	11.6	93.0	47.5
25% Titanium-barium, 75% clay	76.5	13.8	91.9	43.5
(45-Lb. basis raw stock	68.2	19.5	86.7	24.4)

opacity. As previously noted they also show that the greatest improvement in optical properties is obtained at the lower pigmentations since the slope of the curves decreases as pigmentation increases.

Table II. Effect of Calendering

	All clay	*25% Titanium calcium, 75% clay*	*25% Titanium barium, 75% clay*	*10% TiO_2, 90% clay*
25% Starch Adhesive				
Coating, lb. (25×40—500)	8.2	8.2	7.9	7.5
75° Gloss, %				
Uncalendered	1.5	1.5	1.5	1.5
Calendered	19.8	21.1	23.0	21.4
Reflectivity, % (blue filter)				
Uncalendered	73.1	74.9	74.7	75.3
Calendered	69.9	72.7	72.3	72.4
Comparative Yellowness, %				
Uncalendered	16.2	14.7	14.6	14.3
Calendered	17.9	15.7	16.0	15.7
Opacity, %				
Uncalendered	91.7	93.0	92.1	92.4
Calendered	88.9	90.8	90.0	90.4
13% Casein Adhesive				
Coating, lb. (25×40—500)	8.2	7.8	8.5	8.0
75° Gloss, %				
Uncalendered	3.0	3.0	3.0	3.0
Calendered	30.0	34.6	31.0	30.0
Reflectivity, % (blue filter)				
Uncalendered	74.7	79.0	77.4	78.2
Calendered	70.4	74.5	73.7	74.1
Comparative Yellowness, %				
Uncalendered	14.5	11.0	12.2	11.4
Calendered	17.0	14.3	14.7	14.4
Opacity, %				
Uncalendered	91.7	93.6	92.6	92.6
Calendered	88.5	91.2	90.2	90.4

Tests made using a basic mineral mix of 40% calcium carbonate and 60% clay with pigmentations of

10% titanium dioxide and 25% rutile titanium calcium pigment confirm the foregoing observations. In this case, it was necessary to apply the coatings at lower total solids, 37%, since the use of calcium carbonate and the higher starch-pigment ratio (30%) gave a more viscous mix. The paper was lightly calendered from rolls. Here again, 25% rutile titanium calcium pigment gave approximately the same effects as 10% titanium dioxide, as shown in Fig. 8.

All the tests noted above were made using starch as the adhesive. The results obtained with casein (used at 13% adhesive-pigment ratio) with the coatings applied at 44% total solids are very similar to these noted for coatings in which starch was the adhesive. Such data are shown graphically for uncalendered paper in Fig. 9. These curves indicate that 25% rutile titanium calcium pigment gave

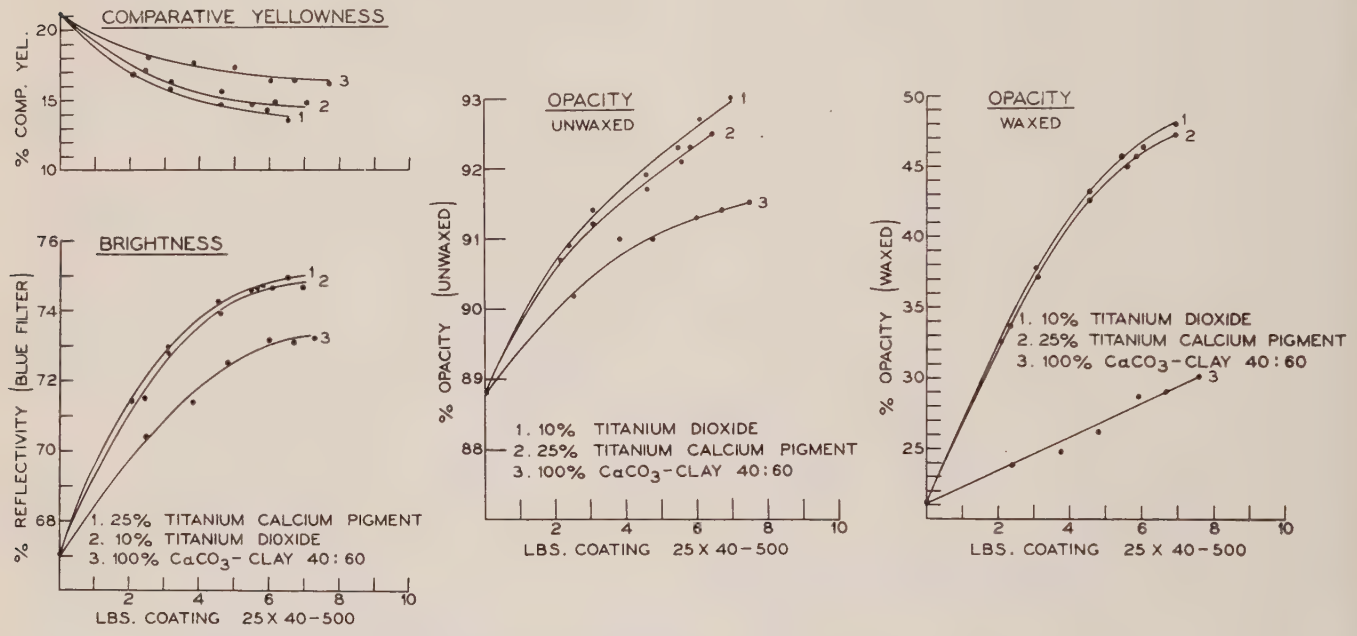

Fig. 8. Calcium carbonate-clay coatings on 45-pound raw stock. Starch adhesive

slightly better brightness and color, slightly higher opacity before waxing, and slightly lower opacity after waxing, than did 10% titanium dioxide. The results obtained with 25% of the titanium barium pigment showed less improvement.

The foregoing discussion has indicated that titanium pigments enhance the optical properties of coated paper regardless of the type of basic coating mix used. It is possible to summarize the results at any given coating weight from the curves, and such a summary is shown for a 6-pound coating in Table I. Such a summary confirms the point noted previously that the titanium barium pigment is less efficient in improving brightness, color, and opacity than the rutile titanium calcium pigment, and that when the latter replaces titanium dioxide in the approximate ratio of 2.5:1 the results obtained are nearly the same.

It should again be noted that the pigmented coatings, regardless of the mineral mix or adhesive used, showed the same rheological properties as the unpigmented. Other mixes in which casein was replaced with a half-and-half mixture of casein cut with soda ash and Dow 512K latex emulsion showed similar rheological properties whether pigmented with titanium dioxide or rutile titanium calcium pigment indicating that both are compatible with the latex as they are with starch and casein. Optical tests showed that, as in all other cases, about 2.5 parts of the rutile titanium calcium pigment are equivalent to 1 part of titanium dioxide.

As previously noted (*3*) the adhesive requirements of pigmented coatings, as indicated by the wax pick test, is no greater than that of unpigmented coatings. In no case did any of the coatings pick when printed on a Vandercook No. 4 proof press using a typical halftone ink.

In the first two series noted above the paper was lightly calendered from rolls, while in the third the paper was uncalendered. Since the gloss-developing characteristics of coated paper are important, more extensive tests were made on samples selected to give approximately the same coating weight in which the paper was sheet calendered through five nips (Table II). The gloss developed for the pigmented coatings was at least as good as for the unpigmented coatings demonstrating that it is possible to make high-gloss finishes with coatings in which titanium pigments are incorporated. The casein coatings all developed greater gloss than the starch coatings. As would be expected, there was a certain loss of opacity, brightness, and color upon calendering, this loss averaging no more for the pigmented coatings than for the unpigmented, and being less in most instances. The casein coatings all developed better brightness, color, and opacity than the starch coatings which is not surprising since the adhesive ratio was lower for the

former and it is known that adhesive ratio has a definite effect on optical properties (*5*). These results also indicate that the titanium barium pigment was less effective than the rutile titanium calcium pigment in improving brightness, color, and opacity and that 25 parts of the latter are approximately equivalent to 10 parts of titanium dioxide in this regard.

ECONOMIC CONSIDERATIONS

The experimental data have indicated that the pigmentation of typical "clay coatings" enhances the optical properties of coated paper very materially. The approximate cost of effecting such improvements is shown by the examples given in Table III. The cost data are based on the average delivered price of the various raw materials involved which vary somewhat with different localities and market conditions. It will be noted that the cost of pigmenting a coating depends on the amount of coating applied per ton of paper whose basis weight varies although the coating weights given in Table III for the various basis weights of coated paper seem reasonable. Casein coatings for off-machine coated papers are basically somewhat higher in cost than starch coatings used for paper coated on the paper machine. Pigmenting a starch-clay coating with 5% titanium dioxide would increase the cost about \$3.35 to \$3.70 per ton of coated paper; the use of 12.5% rutile titanium calcium pigment to produce the same results would be approximately 50 cents lower than these figures. Doubling the pigmentation would increase the cost over the unpigmented coatings from \$7.10 to \$8.10 per ton of finished paper for titanium dioxide and from about \$5.90 to \$6.25 for the rutile titanium calcium pigment. In the casein coating illustrations given the increased cost of pigmenting with 5% titanium dioxide would be about \$2.25 to \$3.00 per ton of coated paper while the use of 12.5% rutile titanium calcium pigment would be about a dollar below these figures; for double this pigmentation the cost would be approximately \$6.00 to \$8.00 for titanium dioxide and from \$4.40 to \$5.70 for the rutile titanium calcium pigment.

These estimates show that the cost of pigmenting coatings for typical publication and printing papers may be somewhat less than usually supposed, with the smaller but still definite improvement increasing the cost in the neighborhood of \$2.00 to \$4.00 a ton of coated paper, while the higher pigmentations, and hence greater improvement, increasing the cost by about double these amounts. In view of the price range in which such coated papers fall, the percentage increase in cost resulting from pigmentation is not very great. The increased cost of pigmenting with the rutile titanium calcium product is somewhat less than using titanium dioxide, especially with the higher pigmentations, varying from 40 to 50 cents less per ton of coated paper for the lower-pigmented starch coatings to as much as \$2.00 a ton for higher-pigmented casein coatings. From the data given, the rutile titanium calcium pigment apparently offers economic advantages over titanium dioxide.

The same observations apply in general to coated paperboards. These are frequently coated with 3 to 4 pounds per thousand square feet of a casein coating whose mineral component contains 10 to 15% titanium dioxide, the pigmentation being essential to insure

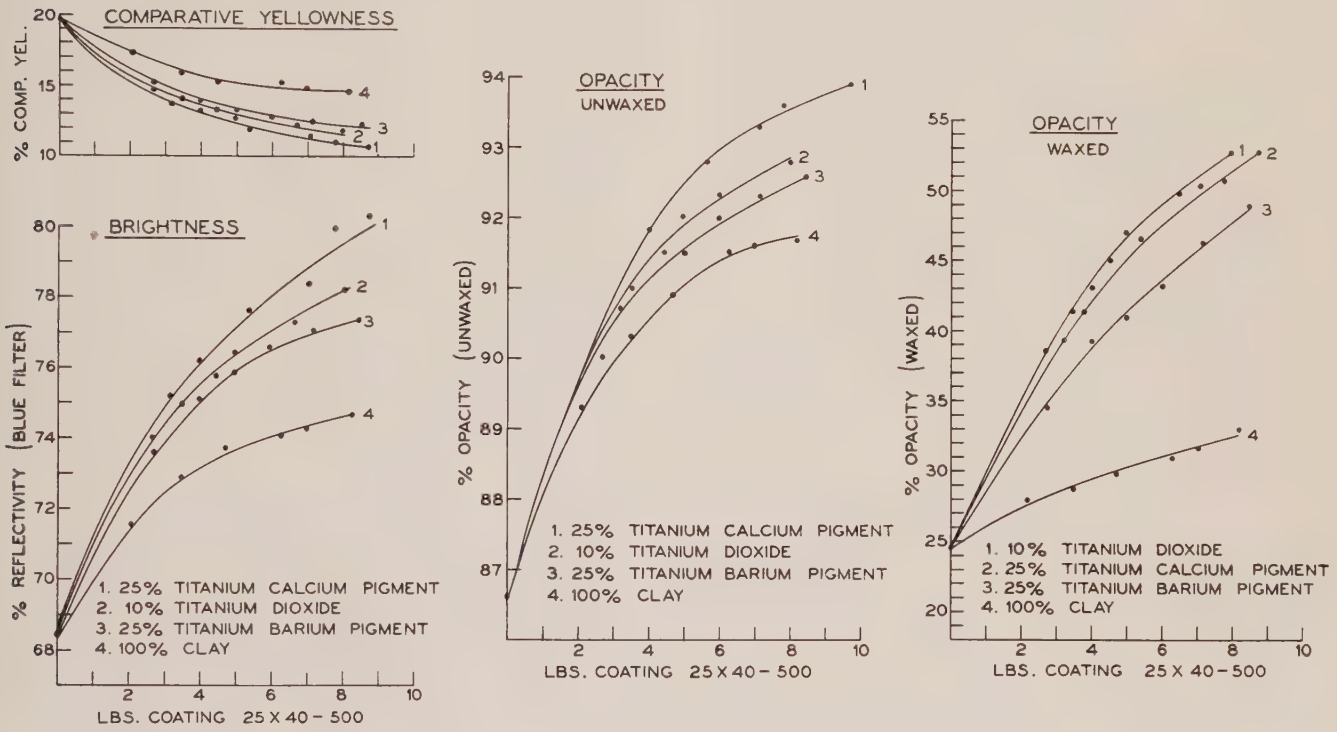

Fig. 9. Clay coatings on 45-pound raw stock. Casein adhesive

proper covering. At the lower coating weight the added cost of pigmentation would be about 5 to 7 cents per thousand square feet, respectively, and for the higher coating weight 6 to 9 cents. The pigmentation cost per ton of board would naturally depend on the weight of the board and, respectively, would be $1.20 to $1.65 for a 24-point board for the lighter weight coating and $1.40 to $2.15 for the heavier weight coating; for a 16-point board these figures would be, respectively, $1.55 to $2.20 for the lighter weight coating and $1.85 to $2.80 for the heavier weight. Replacing the titanium dioxide with rutile titanium calcium pigment in the ratio of 1:2.5 would lower the pigmentation cost by 1 to $1^1/_2$ cents per thousand square feet or from about 25 to 50 cents per ton, depending on the weight of the board.

Table III. Approximate Cost of Pigmenting Coatings

	Cost coating mix per 100 lb., dollars	*Cost coating per ton of coated paper, dollars*				
Basis weight—coated paper, lb. 25×38—500	40	50	60	70	80
Coating lb., 25×38—500	10	12	14	16	20
Lb. per ton coated paper	500	480	466	457	500
Coating mineral composition					
All clay	2.30	11.50	11.04	10.74	10.54	11.50
5% Titanium dioxide	3.04	15.20	14.59	14.17	13.89	15.20
$12^1/_2$% Titanium calcium	2.93	14.65	14.06	13.65	13.39	14.65
10% Titanium dioxide	3.86	19.30	18.53	17.99	17.64	19.30
25% Titanium calcium	3.55	17.75	17.04	16.54	16.22	17.75

Casein Adhesive (Off Machine Coated)

	Cost coating mix per 100 lb., dollars	*Cost coating per ton of coated paper, dollars*		
Basis weight—coated paper, Lb. 25×38—500	60	70	80
Coating lb., 25×38—500	20	20	20
Lb. per ton coated paper	666	592	500
Coating mineral composition				
All clay	5.10	33.97	30.19	25.50
5% Titanium dioxide	5.55	36.96	32.86	27.75
$12^1/_2$% Titanium calcium	5.37	35.76	31.79	26.85
10% Titanium dioxide	6.32	42.09	37.41	31.60
25% Titanium calcium	5.96	39.69	35.28	29.80

In the coating of opaque waxing stock, the rutile titanium calcium pigment offers definite economic advantages over the titanium barium pigment, which was widely used for this purpose prior to its discontinuance. If the coating was applied at a very light weight, in the neighborhood of 2 pounds per ream (24×36—500), the titanium barium pigment was frequently fortified by adding titanium dioxide to the formula, if the coating were heavier, in the neighborhood of 4 pounds per ream, the titanium barium pigment was frequently extended by the use of clay. Laboratory tests have indicated that the rutile titanium calcium pigment is 20 to 25% more effective in producing opacity after waxing than the titanium barium pigment. This was confirmed in actual mill trials where it was found that in a 2-pound coating a mixture of half and half of rutile titanium calcium pigment and titanium dioxide gave about 20% more coverage (as shown by opacity after waxing) than a similar mixture made with the titanium barium pigment and titanium dioxide. In another case in which a 4-pound coating was applied a mixture of 62.5% rutile titanium calcium pigment and 37.5% clay gave an opacity of 57.7% and a brightness of 76% after waxing as compared with 55 and 74%, respectively, for a similar mix made with the titanium barium pigment. When the opaque pigment in the mineral constituent was increased to 87.5%, an opacity of 61% and a brightness of 76.4% (after waxing) was obtained for the rutile titanium calcium pigment as against 59 and 75.5%, respectively, for the titanium barium pigment.

Commercial application has confirmed laboratory findings that the rutile titanium calcium pigment is considerably more effective in paper coatings than is the titanium barium pigment. This shows a definite economic advantage for the former, especially as the titanium barium pigment (prior to its discontinuance) sold at a slightly higher price. The rutile titanium calcium pigment also offers some economic advantage over titanium dioxide although this is somewhat less than the advantage shown over the titanium barium pigment.

While it is true that rutile titanium dioxide has greater hiding power than the anatase form referred to throughout this article, the advantages which might ensue from its use in paper coatings are offset by its higher cost. Furthermore, the rutile form tends to have slightly lower brightness and poorer color, and is somewhat harder and therefore probably more abrasive than anatase.

From the data presented it appears that the improvements in coated paper resulting from pigmentation can be produced at reasonably low costs. Naturally, each case would be specific in nature but the economics of pigmentation for any such specific case could be readily worked out.

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The Possible Correlation Between Hemicelluloses and the Physical Properties of Bleached Kraft Pulps

FRANCIS T. RATLIFF

Five graded pine kraft pulps (ranging in yield from 43 to 66.4%) were bleached with acidified sodium chlorite, thus giving yields ranging from 41.9 to 50.5% (all yields were determined on the unscreened basis). Physical evaluation and chemical analysis of the bleached pulps showed that, in general, strength properties increased continuously with yield and, also with the hemicellulose content. Handsheets made from the bleached pulps indicated that the area in optical contact was closely related to other pulp properties. Thus, the area of optical contact appears to be a reasonably direct function of the actual bonded area, and the latter (particularly in the early stages of beating) is correlated with the bursting and tensile strengths of the sheet. Apparently the hemicelluloses manifest their effects upon pulp properties by enabling a high specific surface and bonded area to be developed during beating without much decrease in fiber strength. There appears to be some correlation between the hemicellulose content and the physical properties of the bleached pulps, but these relationships are less regular than are those between pulp yield and physical properties. Analyses show that, even in a very raw cook, an appreciable amount of the alpha-cellulose originally present in the wood is destroyed or degraded, and that potentially important carbohydrate material is lost even under very mild kraft cooking conditions.

THE role of hemicellulosic materials in influencing the papermaking qualities of wood pulps has been the subject of many investigations and much speculation. Work in this field has been, and is still hampered by analytical methods which are admittedly not of the best and solubility separations which are certainly imperfect. At present the hemicelluloses are considered to have shorter chains than the "true" cellulose, and to contain, in addition to some glucose, xylose, mannose, uronic acid, and possibly galactose and arabinose units, together with some methoxyl and acetyl groups. Based upon solubility separations, the hemicelluloses are considered to be those carbohydrate materials soluble in strong alkali (17.5% sodium hydroxide or up to 24% potassium hydroxide). The sugar units in both the alkali-soluble and alkali-insoluble portions of a pulp may or may not consist of copolymers.

Many investigators have noted qualitatively the influence of hemicelluloses on pulp properties with respect to rate of "hydration," amount of swelling, and strength developed on beating. With the advent of methods for separating holocellulose (the entire carbohydrate fraction of wood), without removal of appreciable quantities of hemicelluloses, investigations into the effects of hemicelluloses were encouraged, and the more quantitative aspects were stressed. Jayme and Lochmüller-Kerler (*1*) prepared a series of sulphite pulps from beechwood. These pulps were bleached with acidified sodium chlorite solutions avoiding removal of hemicelluloses, and a relationship was found between the physical properties of the pulps and the hemicellulose content. Furthermore, it was discovered that there existed an optimum hemicellulose content, above and below which the bursting and tensile strengths of handsheets prepared from the pulps decreased. March (*2*) prepared a series of aspen pulps by stepwise extraction of chlorite holocellulose with aqueous potassium hydroxide. In general his results substantiated those of Jayme and Lochmüller-Kerler.

However, there was still a need for extending this type of investigation to the properties of pulps made from softwoods by the kraft process, subsequently delignified with the use of acidified sodium chlorite. Such an investigation should reveal whether the hemicelluloses influence the properties of kraft pulps in the same manner as in holocellulose. At the same time, the application of recently developed techniques for evaluating the area of fiber-to-fiber bonding in a sheet of paper should reveal something about the means through which the hemicelluloses exert their influences on pulp properties.

CHEMISTRY OF HEMICELLULOSES AND EFFECTS OF HEMICELLULOSES ON PULP PROPERTIES

The chemistry of hemicelluloses is a relatively new field of study, as attested by the fact that the term "hemicellulose" was coined by Schulze (*3*) as late as 1891. Most of the early work involved the isolation of alkali-extractable material from the wood itself and the identification of the sugar units in the precipitated extract, apparently in the attempt to isolate and identify homogeneous chemical entities in the hemicelluloses. It was recognized by these early workers that a fairly large portion of the hemicelluloses could not be extracted from the lignified fibers; however, delignification procedures available at that time were without high selectivity in the removal of lignin; the agents employed simultaneously removed large quantities of hemicelluloses and degraded the remainder of the polysaccharide material. The evolution of procedures for the isolation of holocellulose permitted the delignification of the woody tissue without appreciable removal of the hemicelluloses. These methods utilize either chlorine and alcoholic solutions of organic bases or acidified solutions of sodium chlorite.

An excellent review of the literature dealing with the isolation and study of hemicelluloses has been given

FRANCIS T. RATLIFF, Johns-Manville Research Laboratories, Manville, N. J.
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by Thomas (*4*). In addition, reviews have been published by Norman (*5, 6*). Wise and co-workers (*7–9*) have modified the acidified sodium chlorite method of Jayme (*10*) for the preparation of holocellulose. The modified method requires only three to four hours as compared with 20 to 48 hours for the original method, and has been used in the analysis of a number of woods. March (*2*) has reviewed the literature dealing with the effects of hemicelluloses in papermaking and has demonstrated experimentally, with pulps derived by alkaline extraction of aspen holocellulose, the beneficial effects of an optimum content of hemicelluloses on the physical properties of these pulps. Wise (*11*) has stressed the importance of hemicelluloses and reviewed the major contributions in this field. Inasmuch as these recent literature surveys cover the earlier work rather thoroughly, no further details will be given here.

BEATING THEORY

Other things being equal, a pulp rich in hemicelluloses, upon comparison with one low in hemicellulose content, is found to be more easily hydrated, and to produce a sheet of paper which is harder and less opaque and which possesses higher bursting and tensile strengths and lower tearing resistance. An appreciation of the development and present state of the theory of beating is prerequisite to any investigation into the mechanism through which these effects are manifested.

The theory of beating has been a controversial subject for many years. Most of the conflicting ideas can be classified as belonging to one of three broad schools of thought. Adherents to the chemical theory consider that, during the beating operation, a chemical union of the pulp with water takes place, and that the resulting gelatinous hydrate cements the fibers together. Protagonists for the physical theory postulate the necessity of fibrillation with a resultant intertwining of the fibrils to cause the fibers to adhere in the sheet of paper. Some of the features of each of these two theories were combined by Campbell (*12, 13*) to form the basis of the now widely accepted physicochemical theory of beating. Many excellent summaries and reviews of the literature of beating theory have been given within the past ten years. Allison (*14*) and Bletzinger (*15*) have outlined the conflicting views of the several schools. Clark (*16, 17*) has reviewed critically the state of the beating theory and presented evidence for what he terms "a composite theory of beating." Sutermeister (*18*) has reviewed the beating phenomena and very recently Campbell (*19*) has reoutlined his own ideas on the subject. Hence, there is no necessity of a further detailed review at this point.

Presentation of Problem

The principal objective of this investigation was to discover whether there was a relationship between the physical properties and the hemicellulose content of bleached kraft pulps. To accomplish this, it was necessary to prepare a series of bleached kraft pulps differing from one another principally, and, if possible, only in their hemicellulose content. Therefore, a series of kraft cooks was made on a single lot of coniferous wood chips. By varying the cooking conditions pulps were prepared which covered as wide a yield range as possible. The unbleached pulps were delignified with acidified sodium chlorite to avoid appreciable loss of hemicelluloses during bleaching. The bleached pulps were then characterized physically and chemically to determine whether their physical differences could be accounted for by differences in their hemicellulose content. It was realized at the outset that the hemicelluloses of the bleached kraft pulps might well be different from those found in the original wood, and that their effect upon the pulp properties might have been modified by the cooking process.

A qualitative description of the effects of hemicelluloses upon the papermaking characteristics of pulps led to the belief that they may be brought about through changes in the fiber-to-fiber bonding in the sheets made from the pulps. Parsons (*20*) recently developed a method for evaluating the amount of fiber bonding in handsheets, and the application of this method to the various pulps gave some information about the manner in which the hemicelluloses exert their influence upon pulp properties. In addition, it was expected that the application of such a fundamental study to a series of related pulps might lead to the formulation of some basic ideas regarding the beating theory and the strength of paper.

Preparation and Bleaching of the Kraft Pulps

Selection and Preparation of Wood. Slash pine (*Pinus caribaca* Morolet) wood was used in this study. This species was selected because of its importance as a pulpwood, and because of the existence of a large amount of analytical data on slash pine wood of approximately the same size and age, and obtained from the same source (*9*). Fifteen logs were used. These were 16 to 17 years old, had an average diameter of 7.5 inches, had 50.25% oven-dry content as received, and had a specific gravity of 0.579. The heartwood content of the logs was probably not more than 5%.

One half of each of the fifteen logs was barked by hand and chipped to produce $^3/_4$-inch nominal length chips. These were screened on a $^1/_4$-inch mesh wire screen and hand sorted to remove knots, splinters, and oversize pieces.

Preparation of the Unbleached Kraft Pulps. It was desired to prepare a series of kraft pulps varying in yield and of a lignin content ranging from that of an overcooked to that of a semichemical pulp. The first cooks were made to give a normal to fairly raw kraft pulp. In preparing the remainder of the pulps, these conditions were altered to produce softer or harder pulps. The rawest kraft pulp was prepared by the semichemical process and in this case the cooked chips were defibered with the Bauer pulper. Duplicate cooks were made under each set of conditions to assure an adequate supply of pulp and to obtain checks on the yield data. A résumé of cooking conditions and yields is given in Table I.

Bleaching of the Pulps. The five kraft pulps were bleached with sodium chlorite (analytical grade) in a glass-lined Pfaudler Multi-Mixer equipped with a jacket for exhaust steam or hot water heating. Bleaching conditions were chosen on the basis of the results from a series of small-scale experiments. Constant conditions in all of the bleaching were: consistency,

Table I. Summary of Cooking Conditions and Yields
(The values are averages of the duplicate cooks.)

Pulp cook	A 5 and 6	B 3 and 4	C 1 and 2	D 7 and 8	E[a] 9 and 10
Active alkali (as NaOH), %	26.5	24.5	24.5	24.5	12
Sulphidity, %	20	20	20	20	20
Water ratio, cc./g.	4.5	4.5	4.5	4.5	4.5
Maximum temperature, °C.	172	172	172	172	160
Time to maximum temperature, min.	60	60	60	60	60
Time at maximum temperature, min.	180	97	57	35	60
Time to relieve, min.	15	15	15	15	
Total time, min.	255	172	132	110	120
Digester number	3	3	3	3	Rotary
Unscreened yield, %	43.0	45.8	49.6	51.9	66.4
Screened yield, %	43.0	45.4	47.6	45.0	64.5
Screenings, %	0.06	0.70	4.18	13.4	2.99
Permanganate number	14.6	23.0	32.4		
Lignin, %	2.36	4.10	7.08	9.73	22.78

[a] Cooked chips defibered in the Bauer pulper.

5%; temperature, 70–80°C.; pH, 4–5 (achieved with acetic acid). The concentration of analytical grade sodium chlorite was based on the lignin content of the unbleached pulp and was varied, as was the bleaching time. A summary of the bleaching conditions and results is given in Table II.

Table II. Bleaching of the Pulps

Pulp	Sodium chlorite % on lignin	Bleaching time, min.	Brightness, %	Lignin retained in bleached pulp, %
A	750	60	75.5	0.10
B	500	60	75.7	0.08
C	500	60	76.7	0.14
D	500	60	77.4	0.14
E	500	90	76.2	0.58

Measurement of Yield of Bleached Pulp. Because of mechanical loss of pulp during the bleaching and washing operations and because of inaccuracies in consistency determinations, the figures ordinarily obtained for bleached yields are not to be considered precise; hence, small-scale bleaches on air-dried pulps were made. Two grams of pulp were bleached under the same conditions (except for consistency) that had been used in the large-scale bleaching. The results of these analyses are given in Table III. For comparison, bleached pulp yield values, calculated from the lignin content of the unbleached pulps, are given in this same table.

Table III. Bleached Pulp Yields from an Analytical Scale Bleaching

	Analytical yield, %			Calculated lignin-free yield, % based on wood	
Pulp	Based on unscreened pulp	Based on wood Unscreened	Screened	Unscreened	Screened
A	97.46	41.9	41.9	42.0	42.0
B	95.52	43.7	43.4	43.9	43.5
C	92.34	45.8	44.0	46.1	44.2
D	89.88	46.6	40.4	46.9	40.6
E	76.10	50.5	49.1	51.3	49.8

The agreement between the analytical and the calculated yields may be considered satisfactory. The discrepancy between the analytical and calculated values increases as the lignin content of the unbleached pulp increases. This may have been caused either by removal of labile hemicelluloses as the lignin was removed, or by the failure of the Klason technique to estimate the true lignin content of the unbleached pulps.

It should be emphasized that the entire range of kraft cooking conditions employed gave an over-all bleached pulp yield range of only 8.7%. This range is very much less than that covered by March (*2*), who used aspen holocellulose as a starting material, and considerably less than the yield range covered by Jayme and Lochmüller-Kerler (*1*) in their study of beech sulphite pulps.

The yield data in Table III have been determined on the basis of both unscreened and screened yields. Inasmuch as the screened yields are discontinuous with the severity of cooking, *the chemical and physical data on the pulps have been presented on the basis of the unscreened yields.*

Physical and Chemical Evaluation of the Bleached Pulps

Physical Evaluation of the Bleached Pulps. The bleached pulps were evaluated in duplicate with the Lampén ball mill (*20a*); after determination of consistency (*20b*) and Schopper-Riegler freeness (*20c*), the pulps were formed into handsheets according to TAPPI Standard T205 m and tested according to TAPPI Standard T220 m. The results are presented in Table IV. These data are illustrated in Fig. 1, in which the properties, after beating 40 minutes, are plotted against pulp yield.

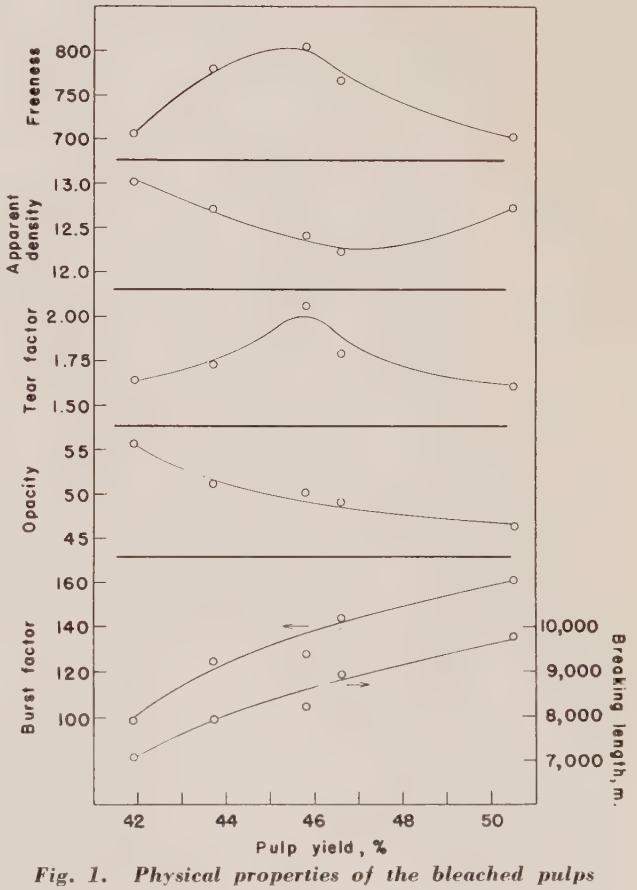

Fig. 1. Physical properties of the bleached pulps

Freeness and Relative Ease of Beating of the Pulps. As may be seen in Fig. 1, the freeness of the pulps, at a given beating time, passes through a maximum as a function of yield. This does not necessarily mean that the pulps in the middle of the yield range are harder to beat than those of lower yield. This in-

terpretation of the significance of the freeness test has been the subject of much conjecture (*21*). Other indications, such as the rate of development of strength in the beater and the rate of development of specific surface, would lend credence to the belief that the high-yield, high-hemicellulose content pulps are easier to hydrate than are the lower yield pulps.

Apparent Density. The apparent density, at a given beating time, passes through a minimum, as a function of pulp yield, at about 46.5% yield. The discontinuity in this curve is caused by the highest yield pulp. This pulp was produced by the kraft semichemical process and the cooked chips were defibered with the Bauer pulper. However, inasmuch as this is the only strength property in which this pulp alone deviates from continuity, it is improbable that the physical defibering was responsible.

Opacity. During the early stages of beating, as shown in Fig. 1, the TAPPI opacity follows the expected relationship with burst and tensile strength—i.e., the higher the burst or tensile, the lower the opacity. That this relationship no longer holds strictly in the later stages of beating may be seen from the data of Table IV. Actually there is an increase in the opacity of some of the handsheets as the pulps are beaten further. This may be accounted for by one of two reasons: (a) the contrast ratio could increase because of advanced maceration of the pulp fibers with subsequent increase in the amount of fiber-air interface capable of scattering light; (b) well-beaten pulps occasionally exhibit an extraordinary drop in reflectance values because of impurities in the water in which they were beaten; this drop in reflectance would cause the opacity to increase.

Table IV. Physical Properties of the Bleached Pulps

Beating time, min.	*S.-R. freeness, cc.*	*Basis weight, (25 × 40—500), lb.*	*Apparent density*	*Opacity (TAPPI)*	*Burst factor, %*	*Tear factor*	*Breaking length, meters*	*Stretch, %*
				Pulp A				
0	870	46.1	9.8	65.5	55	4.10	3,620	2.8
20	840	45.1	11.9	57.4	88	2.10	6,400	2.8
40	705	45.8	13.0	55.6	98	1.64	7,100	3.0
75	280	46.2	14.4	56.7	107	1.25	7,700	3.0
				Pulp B				
0	870	45.0	9.8	63.4	61	3.84	3,400	2.8
20	850	44.7	11.9	54.0	110	2.22	6,900	2.8
40	780	45.0	12.7	51.0	124	1.72	7,900	3.0
80	365	45.8	13.8	50.0	135	1.38	8,400	3.4
				Pulp C				
0	880	46.4	9.7	64.8	66	4.45	3,950	2.8
20	860	47.4	11.8	52.8	114	2.70	7,350	2.6
40	805	44.9	12.4	50.0	127	2.06	8,370	3.0
75	450	46.6	13.2	49.6	140	1.52	9,400	3.2
95	290	46.3	13.7	51.5	145	1.38	9,720	3.2
				Pulp D				
0	865	44.0	10.0	61.5	66	4.00	3,410	2.6
20	835	45.4	11.7	51.8	129	2.15	7,860	3.1
40	765	44.8	12.2	49.0	144	1.78	8,970	3.4
80	430	46.2	13.2	50.1	152	1.42	9,650	3.5
				Pulp E				
0	865	47.1	10.2	61.5	74	4.50	4,300	3.4
20	830	46.6	12.4	49.6	146	1.86	8,500	3.4
40	725	46.8	12.7	46.2	161	1.60	9,750	3.6
75	450	46.7	13.3	44.5	173	1.30	10,500	3.6
95	305	46.4	13.6	43.8	176	1.18	10,850	3.9

Bursting Strength. The burst factor, after 40 minutes of beating time, is plotted against the pulp yield in Fig. 1. This figure demonstrates that there is a continuous rise of bursting strength with yield throughout the entire yield range. This is in contrast to, but not necessarily in conflict with, the conclusions reached by Jayme and Lochmüller-Kerler (*1*) and March (*2*)—i.e., that the strength properties pass through a maximum as the yield and hemicellulose content of a pulp are increased. These investigators were able to work with pulps covering much wider yield ranges than those pulps produced by the kraft process. The extraordinarily high burst factor obtained with pulp E is worthy of mention.

Tensile Strength. The tensile strength data, as illustrated in Fig. 1, indicate that, as expected, the tensile strength follows the same general trend as that observed for the bursting strength.

Tear Factor. It is interesting to note, in Fig. 1, that, as a function of yield, the tear factor passes through a maximum, for a given beating time, at about 46% yield. The spread, for a given beating time, between the highest and lowest tear factors is much less than that for bursting strength.

Evaluation of Area of Optical Contact. The following terms are used in the derivation and expression of the various coefficients employed:

R_0 = absolute reflectance of a sheet of paper or layer of any material when backed by a black body—i.e., a body having a reflectance of zero

R_∞ = absolute reflectance of a sheet of paper or a layer of any material when backed by an opaque pad of the same material. The pad is judged to be "infinitely thick" insofar as light is concerned if doubling the thickness does not change the reflectance reading

$R_{0.89}$ = absolute reflectance of a sheet of paper when backed by a body having a reflectance of 0.89. The effective absolute reflectance of the "white body" of the Bausch and Lomb opacimeter is 0.89
S = scattering coefficient, the limiting value of the relative light intensity per unit thickness scattered backwards from an imaginary layer of a material as the thickness of the layer becomes very small
X = caliper
S' = specific scattering coefficient = SX/basis weight
TAPPI opacity or contrast ratio = $R_0/R_{0.89}$
Printing opacity = R_0/R_∞

Parsons (*20*) has devised a method which permits evaluation of the area of optical contact within a sheet of paper. A brief outline of the assumptions and techniques employed follows.

The basic assumptions of the method are: (a) if a pulp mat is made in such a manner as to preclude fiber-to-fiber bonding, the specific scattering coefficient (S') is a linear function of the specific surface area; (b) in a sheet of paper, S' is a linear function of the area not in optical contact following the same function assumed in (a). This is based on the fact that light is refracted or scattered only at interfaces involving contact between two media of differing refractive index—for example, cellulose and air. If the surfaces of two media possessing the same refractive index are brought into optical contact, light scattering at the interface is eliminated. Obviously, the difference between the specific surface of the pulp and the area not in optical contact is equal to the area in optical contact. This then, is the area removed from light scattering by fiber-to-fiber bonding during the formation and drying of the sheet, and the area not in optical contact is a measure of the specific surface of the sheet of paper.

In order to correlate S' with specific surface, Parsons displaced water from a quantity of unbeaten pulp, the specific surface of which had been obtained by Clark's method (*16*) as modified by McEwen (*22*). This was accomplished by washing the pulp repeatedly with acetone (boiling range 55.5 to 57.5°C.), followed by washing with butyl alcohol, C.P. grade (boiling range 116 to 118°C.). Handsheets were made from a suspension in butyl alcohol, following the observation of Kress and Bialkowsky (*23*) that this solvent exerts no swelling action on cellulose. S' as obtained on this unbonded pulp was plotted against the specific surface as a one-point correlation, the line passing through the origin. Using this correlation and S' data for normal handsheets, figures were obtained for the area not in optical contact. Parsons found a definite correlation between strength characteristics and the bonded area determined with this technique.

The area in optical contact should be a very important property of a sheet of paper inasmuch as it should be at least a function of, if not a direct measure of, the area involved in fiber-to-fiber bonding. The area of fiber bonding should be one of the few fundamental strength properties of a sheet of paper, together with fiber strength, fiber length, and strength per unit area of fiber bonds.

Experimental data on the maximum distance by which two surfaces may be separated and still remain in "optical contact" are lacking or have not been found. Wood (*24*) and Planck (*25*) both state that, if light travels through a dense medium toward a rarer medium along the path of the angle of total reflection, a disturbance will be felt by a particle in the rare medium at a distance as far as one wavelength of light from the interface. This would indicate that optical contact implies a separation of less than one wavelength. Other considerations, based on reflection of light from an interface at normal incidence (*26*), lead to the belief that there is no sharp line of demarcation between the presence and absence of optical contact. Total absence of reflection at an interface, which would indicate complete optical contact, could occur only at extremely small distances of separation. As the distance of separation becomes larger, the reflectance becomes larger and the indication of optical contact becomes vanishingly small as the distance approaches a small fraction of one wavelength. It may be inferred, therefore, that by optical contact an average maximum separation of the order of a small fraction of one wavelength (0.6 micron or 6000 Angstrom units in this work) is indicated.

To complete the analogy between area of optical contact and area of fiber bonding, some information is necessary concerning the distances through which the forces which are responsible for fiber bonding act and the minimum discontinuities which are discernible by the Clark silvering technique for specific surface area.

The very nature of the forces which bond fibers in a sheet of paper is obscure. In a discussion by H. Mark (*27*), it is generally conceded that rupture is seldom caused by failure of primary valence forces, which act over distances of a few Angstrom units or less than 1 mmu. van der Waal's forces, which may be involved in fiber bonding, act through separations of the same order of magnitude. Hydrogen bonds, considered by Rodebush (*28*) to be important in fiber bonding, also act over similar distances. It is possible that fibers may be bonded by hydrogen bonds acting across one or more water molecules. This would increase slightly the possible distances of separation. Campbell (*12*) has analyzed surface tension forces and found them to be very large (of the order of several hundred atmospheres pressure) during the drying of a sheet of paper. These forces probably would draw any fibrillae within proximity of each other into contact close enough to permit the action of bonding forces, irrespective of their nature.

McEwen (*22*) has determined that, in the Clark technique for specific surface, from 2 to 6 mg. of silver per gram of fiber are deposited during the silvering operation. The pulp he used had a specific surface of 10,000 square centimeters per gram. Assuming a continuous film of silver, having a specific gravity of 10, the thickness of the film may be calculated to be from 200 to 600 mmu. Fibrillae of less than 30 mmu diameter have been detected by the electron microscope (*29*), and there is no reason for believing that much smaller filaments do not exist in a well-beaten pulp. These very small fibrillae would be coated with silver and their contribution to the specific surfaces magnified because of the thickness of the film of silver. However, a crevice on a fiber or a roughness on the

surface of a fibril having dimensions of the order of 400 mmu probably would be undetected because of the smoothing effect of the film. A portion of this kind of surface could participate in fiber bonding. It is seen that the specific surface measurement may be insensitive to some areas which might become bonded but, at the same time, a compensating effect is achieved through magnification of the area of very small fibrillae.

The distances involved in fiber bonding and in optical contact are, on a theoretical basis, fairly close in orders of magnitude. This belief is encouraged by the knowledge that any unobstructed fibrillae coming within the distance of optical contact would be drawn close enough to bond by the surface tension forces. The scattering coefficient, which is the determinator of the criteria of optical contact, is correlated with the specific surface. The measurement of specific surface with the tools employed does not detect differences as small as those shown by the scattering coefficient. Nevertheless, the scattering coefficient does correlate with the specific surface and, therefore, it is

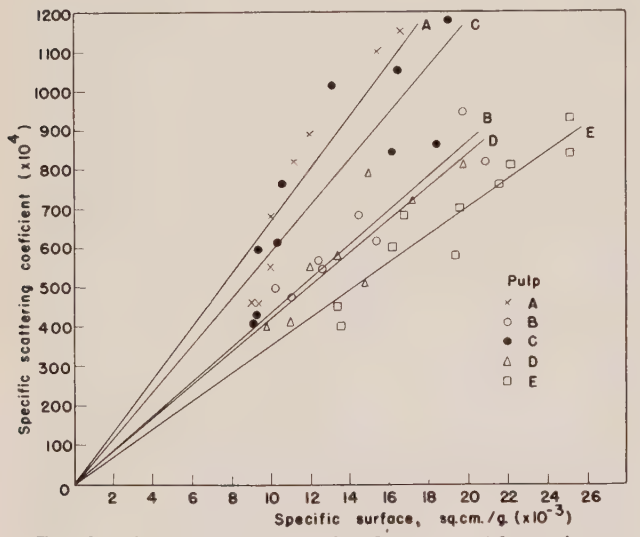

Fig. 2. Scattering power of pulp vs. specific surface

concluded that the data obtained for the area of optical contact should bear some relationship to the bonded area and should be capable of correlation with other physical properties of a sheet of paper. Bearing in mind the probability that the area of optical contact as measured is only a function of the actual area of optical contact and not necessarily a direct measure of the bonded area, hereafter this area will be called "bonded area" and the area not in optical contact the "unbonded area."

Data on the specific surface and the optical properties of the pulps and the handsheets therefrom were obtained at each of the duplicate intervals of beating. The optical properties were measured with the General Electric recording spectrophotometer at 600 mmu wavelength.* The Bureau of Standards opacity charts (*30*) were used to obtain scattering coefficients from the optical data. The data are summarized in Table V.

* These measurements could be made less conveniently on simple instruments without great loss in precision.

To check the assumption that the S' value of an unbonded sheet is a direct function of the specific surface, butyl alcohol sheets were made from the pulps at each interval of beating. Very poor formation was obtained when these sheets were made on a wire from a British sheet mold placed in a Buchner funnel. This was caused by the high stock consistency and the holes in the ceramic Buchner funnel. A small fritted glass Buchner funnel (Jena porosity 1) was substituted for the porcelain funnel and an extension added to permit the use of more dilute stock. Sheets obtained with this arrangement had fair to good formation. The sheets were cut with a round die to give a known area for basis weight determinations. Five thin sheets were made (15 to 25 pounds basis weight, 25 × 40—500) for R_0 measurements and two thick pads for the backing for R_∞ measurements. Two readings of reflectance values were made on each of the five butyl alcohol

Table V. Optical and Surface Properties of the Bleached Pulps

Beating time, min.	Specific scattering coefficient ($S' \times 10^4$) Water sheet	Butanol sheet	Specific surface areas (cm.²/g.) Handsheets (prepared in water) Pulp (Clark) A	Unbonded (from S')B	Bonded (A-B)
			Pulp A		
0	300	454	8,900	4500	4,400
0	301	454	9,300	4500	4,800
20	214	676	10,000	3200	6,800
20	207	550	9,900	3200	6,700
40	202	826	11,100	3100	8,000
40	215	895	11,900	3300	8,600
75	193	1150	16,700	2900	13,800
75	198	1108	15,400	3000	12,400
			Pulp B		
0	302	470	11,100	7000	4,100
0	295	494	10,200	6800	3,400
20	208	542	12,600	4800	7,800
20	195	565	12,400	4500	7,900
40	185	680	14,500	4400	10,100
40	186	616	15,400	4400	11,000
80	176	819	20,900	4100	16,800
80	175	944	19,700	4100	15,600
			Pulp C		
0	285	402	9,100	4900	4,200
0	270	428	9,200	4700	4,500
20	188	597	9,700	3200	6,500
20	188	612	10,400	3200	7,200
40	173	762	10,600	3000	7,300
40	176	1032	13,300	3000	10,300
75	169	848	16,200	2900	13,300
75	167	1056	16,500	2800	13,700
95	172	1182	19,000	2900	16,100
95	167	860	18,400	2800	15,600
			Pulp D		
0	281	399	9,700	6700	3,000
0	292	414	11,000	6900	4,100
20	187	576	13,300	4400	8,900
20	190	554	12,000	4500	7,500
40	172	784	15,000	4100	10,900
40	169	506	14,700	4000	10,700
80	170	719	17,100	4000	13,100
80	171	812	19,700	4000	15,700
			Pulp E		
0	244	396	13,500	6900	6,600
0	240	449	12,400	6800	5,600
20	159	597	16,100	4500	11,600
20	165	676	16,700	4700	12,000
40	143	575	19,400	4100	15,300
40	143	694	18,800	4100	14,700
75	135	755	21,500	3800	17,700
75	136	799	22,100	3800	18,300
95	123	834	25,100	3500	21,600
95	128	925	25,000	3800	21,200

sheets, and one set of reflectance values taken on each of the five normal waterleaf sheets at each interval of beating. Specific surfaces were obtained at each interval of beating using Baker's modification (*31*) of the Clark-McEwen method.

The correlation chart used to obtain the unbonded areas is given in Fig. 2. Parsons' assumption of a straight line for this correlation was correct; however, because of the dispersion of the points, the justification of a one-point correlation is problematical when dealing with different pulps.

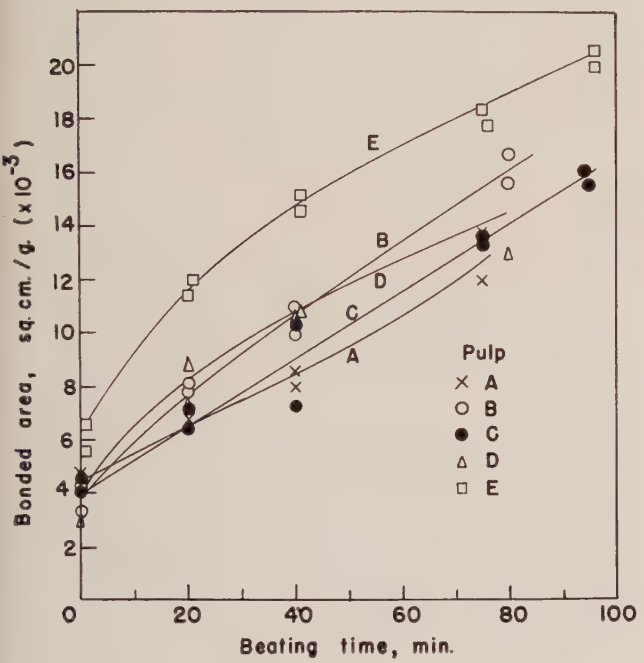

Fig. 3. Bonded area vs. beating time

Figure 3 shows the dependency of the area of optical contact or bonded area on beating time. The bonded area is approximately a linear function of beating time.

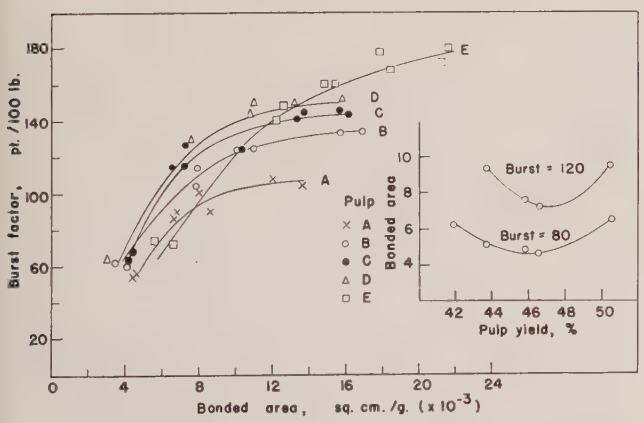

Fig. 4. Bonded area, burst, and yield relationships

In Fig. 4, burst factor is plotted against bonded area. During the early stages of beating, the bursting strength (and tensile strength) increases approximately linearly with bonded area. The slope of the curve during this period is very close to one—i.e., doubling the bonded area doubles the bursting strength. After the initial beating period, the effects of increasing the bonded area diminish, and there is a change in the slope of the curve. At this point, the bonding strength has apparently approached the fiber strength, and sheet failure is caused as much by fiber failure as by bond failure. On the other hand, there likewise exists the possibility that differences in the specific strength of the fiber bonds might account both for the "saturation" effect noted here and for the differences in the ultimate strength of the various pulps. It is also possible that increased fiber bonding may result in increased concentration of stresses at weaker spots; this could account in part for the non-linearity of the strength-bonded area curve.

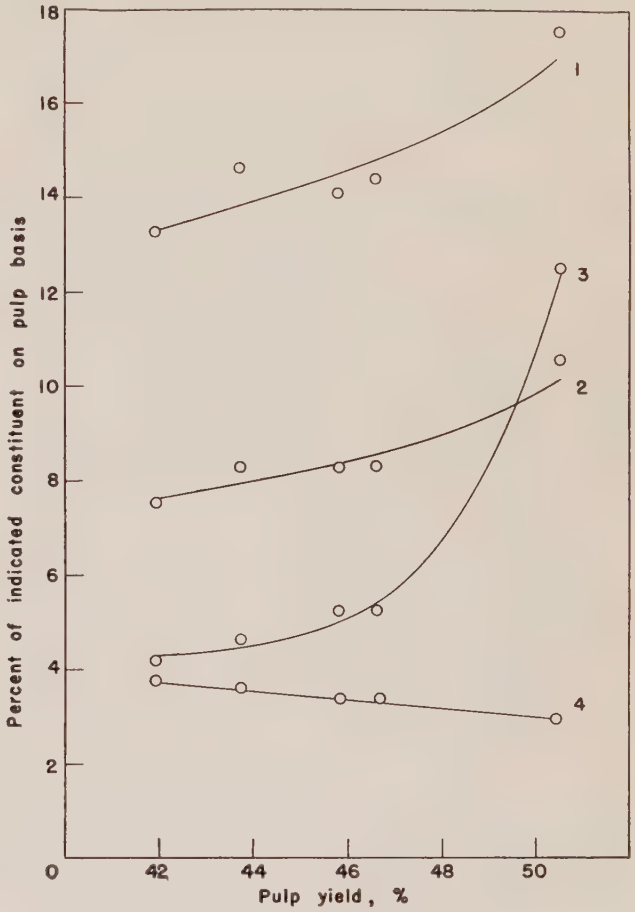

Fig. 5. Hemicellulose-yield relationships

(1) Pentosan and mannan; (2) pentosan; (3) 5% KOH solubility; (4) 24% KOH solubility after extraction with 5% KOH.

Another interesting piece of information which may be derived from the studies on areas of fiber bonding concerns the effect of beating upon the unbonded area. This is illustrated in Fig. 5. The principal source of interest is the rapid decrease of unbonded area on going from an unbeaten pulp to one which has been lightly beaten. These curves show that, particularly during the early stages of beating, the bonded areas are increased through two mechanisms: (a) the surface area increases during beating; (b) a portion of the surface pre-existing in the unbeaten pulp is not bonded in the paper made from the unbeaten pulp but becomes available for bonding when the pulp is beaten.

The initial stages of beating, therefore, not only result in an increase in the specific surface of a pulp but also in a preparation of some of the existing area for bonding. This may consist of a physico-colloidal activation of the surface preparatory to bonding, spoken of by Allison (*14*), or of a mere flexiblization of the fiber which would permit more of the surface to be brought into that intimate contact necessary for fiber bonding.

Chemical Analysis of the Bleached Pulps. The analytical data are presented in Table VI. In all cases, except where noted, the analyses were made in accordance with TAPPI methods.

The analysis of the pulps reveals that the essential chemical differences lie in the hemicellulose content. The lignin and ash contents of the pulps are very low. The degrees of polymerization are sufficiently close so that their differences could not account for the great differences in strength properties.

Table VI. Chemical Analyses of the Bleached Kraft Pulps

	Pulp				
	A	*B*	*C*	*D*	*E*
Yield, %	41.9	43.7	45.8	46.6	50.5
Ash, %	0.20	0.20	0.30	0.32	0.56
Lignin, %	0.10	0.08	0.14	0.14	0.58
Pentosan, %	7.5	8.3	8.3	8.3	10.6
as xylan, %	6.8	7.5	7.5	7.5	9.6
Uronic anhydride, %	1.2	1.2	1.6	1.2	1.2
Mannan, %	5.8	6.4	5.8	6.1	7.0
Degree of polymerization (nitrate)	1450	1130	1220	1260	1380
Alpha-cellulose, %[a]	91.0	91.0	90.8	90.1	84.4
Large-scale alpha yield, %[b]	90.4	....	....	....	83.2
Pentosan, %	3.8	....	....	....	3.9
as xylan, %	3.4	....	....	....	3.5
Mannan, %	5.1	....	....	....	5.8
5% KOH solubility, %[c]	4.2	4.7	5.3	5.3	12.6
24% KOH solubility, %[d]	3.8	3.7	3.4	3.4	3.0
Total KOH solubility, %	8.0	8.4	8.7	8.7	15.6
Total KOH fibrous residue, %	92.0	91.6	91.3	91.3	84.4

[a] Institute Method 421.
[b] 17.5% NaOH under nitrogen—2 hours at 20°C.
[c] Under nitrogen—2 hours at 20°C.
[d] After extraction with 5% KOH.

Several measures of hemicellulose content have been plotted against pulp yield in Fig. 5. These include pentosans, pentosans plus mannan, 5% KOH solubility (corresponding to "hemicellulose A") and 24% KOH solubility after extraction with 5% KOH (corresponding to "hemicellulose B"). Uronic anhydride was not included in these graphs because the uronic anhydride content in all but pulp E is at or below the level of significance. The pentosans and 5% KOH solubility correlate fairly well with the pulp yield. Correlation of pentosans plus mannan with pulp yield is poorer, perhaps, because of experimental difficulties in the mannan determination. It is significant that the 24% KOH solubility after extraction with 5% KOH correlates slightly negatively with pulp yield. This may indicate that some material has been transformed from the alpha-cellulose to the hemicellulose "B" solubility classification. It is also possible that the hemicellulose "B," on the wood basis, remains relatively constant in the pulp.

In Figs. 6 and 7, in which burst factor and specific surface have been plotted against the 5% KOH solubility of the pulps, it is demonstrated that the physical properties of the pulps are at least partially dependent upon the hemicellulose content. The shape of the curve in Fig. 6 might lead to the belief that there could be a maximum in these curves between 8 and 10% solubility in 5% KOH. However, reference to the

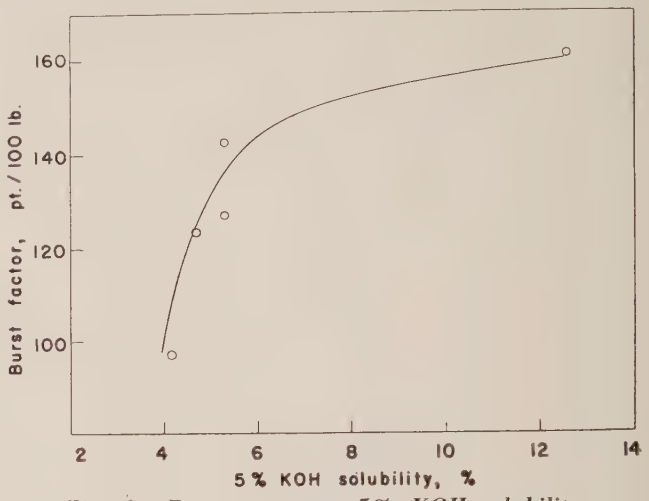

Fig. 6. Burst factor vs. 5% KOH solubility

burst-yield curves of Fig. 1 indicates that it would be difficult to interpolate a maximum in the burst-yield curves. *It should be emphasized that the physical properties are much more sensitive to differences between the pulps than are the chemical properties* (as gaged by analysis). Pulps C and D, having yields of 45.8 and 46.6%, respectively, have been differentiated

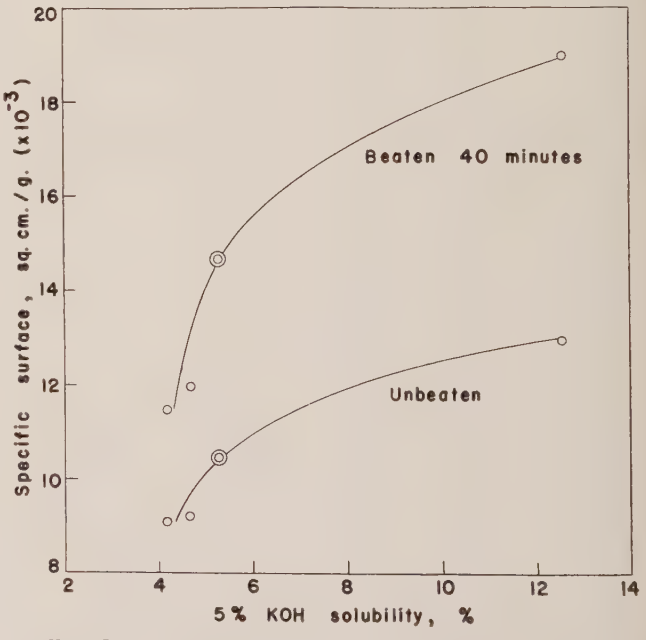

Fig. 7. Specific surface vs. 5% KOH solubility

clearly by the physical testing. However, from an analytical point of view, because of the limited accuracy and scope of the chemical methods, these pulps would be considered "identical."

In obtaining the several measures of hemicellulose content, three different types of determination of alkali

solubility were used. Conventional alpha-cellulose determinations using 17.5% NaOH in open beakers were made on all of the pulps. It was felt desirable to determine the mannan and pentosans on the alpha-cellulose, and large batches (24 grams) were prepared from two of the pulps, A and E, for this purpose. In the preparation of the large batches, 17.5% NaOH was used, but was applied under nitrogen at 20°C. for two hours. Solubility in 5% KOH and in 24% KOH (after extraction with 5% KOH) was determined following the method of Wise and coworkers (*8, 9*), in order to obtain information on the distribution of the hemicelluloses in the solubility classifications of hemicellulose "A" and "B". It is

Table VII. Carbohydrate Retention in Pulps on Solubility Basis

		Pulp analyses on wood basis				
	Wood[a]	*E*	*D*	*C*	*B*	*A*
Extractives, ash and acetyl, %	4.80					
Lignin, %	26.05					
Lignin plus ash, %		0.6	0.2	0.2	0.2	0.1
Alpha-cellulose (uncorrected), %	53.95	42.6	42.5	41.8	40.0	38.5
Hemicellulose A (5% KOH), %	10.3	7.0	2.5	2.4	2.1	1.8
Hemicellulose B (24% KOH), %	3.5	1.5	1.6	1.6	1.6	1.6

[a] Data of Wise and E. K. Ratliff (*9*).

very interesting to note, from the data of Table VI, that the yields of residues obtained by these three methods are in very good agreement. In all cases the differences amount to less than 2% of the determined value.

In an attempt to account for the carbohydrate material in the original wood, the pulp analyses have been calculated back to the wood basis and have been compared with the wood analyses data of Wise and E. K. Ratliff (*9*). In Table VII, these comparisons have been made on the basis of alkali solubility classification, and in Table VIII on the basis of analyses

Table VIII. Carbohydrate Retention in Pulps on Constituent Basis

		Pulp analyses on wood basis				
	Wood	*E*	*D*	*C*	*B*	*A*
Alpha-cellulose (corrected),[a] %	45.4	38.2	37.8	37.5	35.8	34.4
Mannan, %	7.8	3.5	2.8	2.7	2.8	2.4
Xylan, %	8.25	3.2	2.5	2.4	2.5	2.2
Uronic anhydride, %	4.60	1.6	0.5	0.5	0.5	0.5
Lignin in unbleached pulps (on wood basis)	....	15.7	5.0	3.5	1.8	1.0

[a] Corrected for residual xylan and mannan in the alpha-cellulose.

for individual chemical constituents. *These data are striking in that they demonstrate the waste of polysaccharides during the kraft cook.* The unbleached pulp E contained about 15.7% lignin on the basis of the original wood. Comparing lignin and alpha-cellulose (either as such or corrected for residual mannan and pentosan) of the wood and pulp in Tables VII and VIII, it is evident that, in a semichemical cook, the rate of removal of alpha-cellulose is approximately equal to the rate of removal of lignin. Judging from the analyses of the other pulps, it is highly probable that this same state of affairs holds during the early stages of a normal kraft cook.

March (*2*) has noted that the xylan content of the alpha-cellulose prepared from a kraft cook on aspen is higher than that of the alpha-cellulose prepared from aspen chlorite holocellulose. Wise and E. K. Ratliff (*9*) obtained 2.6% pentosan (calculated as xylan) in the alpha-cellulose from a slash pine holocellulose. Alpha-cellulose from the two bleached kraft pulps analyzed contained 3.4 and 3.5% pentosan (calculated as xylan). This is in agreement with the observation of March. However, this does not hold for the mannan content of the alpha-cellulose from the several wood pulp and holocellulose preparations. The mannan content of the alpha-cellulose from slash pine holocellulose was found to be 10.4%, whereas the mannan in the alpha-cellulose from the bleached pulps amounted to 5.1 and 5.8%. Thus, the xylan found in the long-chain portion of the wood is apparently more resistant, and the mannan less resistant to removal in the kraft cook than is the cellulose itself.

DISCUSSION

The five bleached pulps prepared in this study exhibited a wide divergence in physical properties. The bursting and tensile strengths of the sheets prepared from the pulps rise with increasing pulp yield when that yield is expressed on the bleached but unscreened basis. The tearing resistance of the sheets passes through a maximum as a function of yield. The physical properties of the pulps are likewise functions of the hemicellulose content although these functions are not as regular as those relating physical properties with yield. It is probable that there are other factors, in addition to the hemicellulose content as measured, which influence the properties of the pulps. The pulp properties (as functions of yield or hemicellulose content) do not pass through maxima as reported by several investigators of hardwood pulps. However, the yields and hemicellulose contents of the bleached kraft pulps cover a much narrower range than those covered by the earlier investigators who used chlorite holocellulose and sulphite pulps. It is entirely possible that, by using chlorite holocellulose, a pulp could be made from slash pine which would have such high quantities of hemicellulose that the strength properties would actually be impaired. Hence, the results of this study are not in conflict with those of the workers mentioned. However, no conclusions regarding pulps of maximum strength are warranted for this study.

The bleached pulps hydrated more rapidly and, in all cases, produced stronger handsheets than did the unbleached pulps. This, particularly in the case of pulp A, attests to the gentleness of the chlorite bleaching. The strength of the unbleached pulps passed through a maximum as the yield increased and that of the bleached pulps increased throughout the yield range. As the yield of unbleached pulp increased, the hemicellulose content, which is beneficial to strength, increased. At the same time, the lignin content, detrimental to strength, increased. The maximum strength was attained at the point where further increase in

lignin outweighed the beneficial increase in hemicellulose content. It is likewise possible that any lignin-hemicellulose complex in the unbleached pulps prevents the most effective use of the beneficient hemicelluloses.

Using the technique of Parsons (*20*), studies have been made of the areas of fiber-to-fiber bonding within handsheets prepared from the bleached kraft pulps. It has been found that the physical properties of the kraft pulps are functions of the bonded areas. The specific surfaces and bonded areas of the pulps increase approximately linearly with the beating time. The pulps with a high hemicellulose content possess higher original surfaces and develop surface in the beater at a greater rate than do those with a lower hemicellulose content. This appears to be in agreement with the observations of Young and Rowland (*32*) that the swelling capacity in water of softwood pulps falls with decreasing pentosan content, and with the statements of Jayme and Lochmüller-Kerler (*1*) regarding the swelling capacity of a series of beech sulphite pulps possessing varying hemicellulose contents.

The fact that the bonded areas, as measured in this work, correlate in a reasonable manner with the physical properties of the pulps, together with the theoretical considerations and reasoning behind these measurements, lead to the belief that a means has been obtained for measuring a function of one of the few fundamental, determinative strength properties of a sheet of paper. Based upon this information, a generalized hypothesis has been evolved concerning the theory of beating and the origin of strength in paper. This is not a radical departure from present concepts but may be considered as an extension, in the light of newer techniques, of the ideas of Campbell (*12, 13*) Clark (*17*), and other workers in the field.

In a sheet of handmade paper, containing no additives, the principal properties affecting sheet strength are fiber strength, fiber length, amount of fiber bonding, and quality of fiber bonding. From the data obtained in this study, it is postulated that, at least during the early stages of beating, the amount of fiber bonding fairly well controls the sheet strength. As the total strength of fiber bonding approaches the strength of the fibers themselves, fiber strength may increasingly become the limiting factor. Other limiting factors may be the specific strength of the fiber bonds and increased concentration of stresses at weaker spots as fiber bonding is increased. Inasmuch as the beating action decreases the fiber strength and the fiber length at the same time that it increases the specific surface of a pulp, it would appear that a pulp which rapidly develops surface in the beater would undergo less damage in the beating process and give a higher strength sheet. On the other hand, if a pulp develops surface slowly, or with difficulty, by the time an adequately high surface has been obtained, fiber damage has proceeded to such a state that the strength of the resultant sheet of paper has been impaired. It is likewise possible that the original fiber strength of such a pulp is lower than that of an easily hydrated pulp.

The chemical analyses of the pulps indicate that the physical properties are related to the hemicellulose content, but that this relationship, in this series of pulps, is not as satisfactory as that in which the physical properties are considered as functions of pulp yield. The trend of pentosans, mannan, 5% KOH solubility, and total (5% plus 24%) KOH solubility is to increase with pulp yield. The solubility in 24% KOH after extraction with 5% KOH decreases slightly with yield. It is not possible to segregate the effects and come to any conclusion as to whether the mannan or pentosans are responsible for the effects attributed to the hemicelluloses. It should be noted that the sum of mannan and pentosans in the alkali-extractable portion of the pulp accounts for about one half of this fraction. It is generally assumed that the major part of the remainder of this hemicellulosic material consists of glucose units connected either with each other or, possibly, with the other sugar units. It is likewise impossible to isolate the effects of these substances upon the pulp properties. It is possible to state that, of the two solubility classifications into which the alkali-extractable materials have been arbitrarily divided, it is probable that the material soluble in 5% KOH affects the swelling and surface characteristics more than that material not soluble in 5% KOH but soluble in 24% KOH. This is in general agreement with the findings of Greenane (*33*) who was able to correlate physical properties of pulps with their gamma-cellulose content.

SUMMARY AND CONCLUSIONS

1. Five kraft pulps have been prepared and bleached essentially free from lignin by the use of acidified sodium chlorite solutions. The unbleached pulps varied in yield (unscreened basis) from 43.0 to 66.4%. The bleached pulps varied in yield, on the same basis, from 41.9 to 50.5%.

2. Physical evaluation and chemical analysis of the bleached pulps showed that, in general, strength properties increased continuously throughout the yield range and hemicellulose range covered by the series of pulps. The following illustrative examples may be mentioned:

(a) The burst factor, after 70 minutes' beating, on the lowest yield pulp was 105, on the highest yield pulp, 170.

(b) The breaking length, at the same beating time, was 7500 meters for the lowest yield pulp, 10,500 meters for the highest yield pulp.

(c) The tear factor, as a function of pulp yield, passed through a maximum at about 46% yield. The highest yield pulp had, at a given beating time, only a slightly lower tear factor than the lowest yield pulp.

(d) The opacity of the handsheets, at a given beating time, decreased continuously with yield or hemicellulose content.

(e) The apparent density of the handsheets, at a given beating time, passed through a slight maximum at about 46% yield.

(f) The relative ease of hydration, as measured by rate of increase of burst or tensile strength and by rate of development of specific surface, increased with yield and hemicellulose content. The freeness of the pulps at a given beating time passed through a maximum, depending upon the time of beating, at from 44 to 46% yield.

3. Measurements of the areas in optical contact within the handsheets from the bleached pulps have been made at each interval of beating. These areas have been related to the other properties of the pulps, and the following conclusions drawn:

(a) From both experimental and theoretical information, it becomes evident that the area in optical contact, as measured, is a reasonably direct function of the actual bonded area within the sheet of paper.

(b) The bursting strength and tensile strength of the handsheets correlate with the bonded areas, and, particularly in the early stages of beating, are probably predominantly dependent upon the bonded area. In the later stages of beating the slope of the bonded area–strength curve changes in such a manner as to indicate that the bond strength is approaching the fiber strength, and that fiber strength is probably one of the limiting factors determining the strength of the paper together with specific strength of fiber bonds and increased stress concentration as bonding increases.

(c) The relationships among specific surface, bonded areas and yield, and hemicellulose content lead to the belief that the hemicelluloses manifest their well-known effects upon pulp properties by enabling a high specific surface and bonded area to be developed in the beater without large decrease in actual fiber strength. It is also probable that a pulp containing large quantities of hemicelluloses possesses a higher original fiber strength than one with low hemicellulose content. Loss of fiber strength on extraction of hemicelluloses may be caused by lowering of bonded areas within the fiber as the hemicelluloses are removed.

4. Chemical analyses of the pulps indicate that the hemicellulose content of the pulps correlate with the physical properties, but these correlations are not as regular as those of the pulp yield with physical properties. Likewise, it is not possible to assign any effects to specific units in the hemicelluloses other than stating that the effects found are probably more closely related to the hemicelluloses of short-chain length than to those of longer chain length.

5. When the chemical analyses of the pulps are calculated on a wood basis and compared with published chemical analyses of slash pine wood, it becomes evident that, even in the highest yield kraft pulp, a large quantity of the alpha-cellulose originally present in the wood has been lost or degraded during the pulping process. Actual kraft pulp yields fail to approach the potential carbohydrate materials present in the wood.

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Measurement of Slush Stock Flows

G. D. ZIMMERMAN

The principles and operation of a variable area meter which is being used to proportion slush stocks are described briefly.

THE PROCESS and economy of a pulp and paper mill hinge on its flows of slush stock. The methods of metering and controlling these stock flows have changed little in the past forty years. During this time the industry has used variations of a rotating "compartment" meter, not unlike a water wheel. The theory of this unit's operation is based on volume measurement, each revolution being totalized on a mechanical counter. In an effort to eliminate the installation difficulties inherent in this type of equipment due to its bulk and at the same time provide a stock meter of greater accuracy, lower cost, and greater ease of operation, the Ratosleeve meter was modified to meet stock metering requirements.

In its simplest form the variable area meter consists of two parts: a tapered tube set vertically in the fluid piping system with its large end at the top, and a metering float which is free to move vertically in the tube. When no fluid is flowing the float rests at the bottom of the tapered tube and its maximum diameter is so chosen that it blocks the small end of the tube almost completely. When flow commences in the pipeline and the fluid reaches the float, the buoyant effect of the fluid lightens the float. However, as the float has a greater density than the fluid, the buoyant effect is not sufficient to lift the float. Therefore, the flow passage remains blocked and fluid pressure starts building up. When the upward fluid pressure, plus the fluid buoyant effect, exceed the downward pressure caused by the weight of the float, then the float rises and truly "floats" in the fluid stream. As the float rises toward the larger end of the tapered tube, an annular passage is opened between the inner wall of the tube and the periphery of the float and through this opening the fluid passes. The float continues to rise till the annular passage is large enough to handle all the fluid coming through the line. Then the fluid velocity pressure drops till it, plus the fluid buoying effect, exactly equals the float weight. The float then comes to rest in dynamic equilibrium. Any increase in flow rate causes the float to rise higher in the tube, and a decrease causes it to sink to a lower level. Every float position corresponds to one particular flow rate and no other. It is merely necessary to provide a calibration scale on the outside of the tube and flow rates can be read directly.

The modified unit for slush stock service comprises three component parts: a tapered stainless steel spool piece (the tube) complete with lower float guide assembly, a streamlined stainless steel metering float, and an indicating or recording or telemetering head integrally mounted on a cover flange and complete with upper float guides. The flow of stock enters the bottom fitting, passing vertically through the tapered spool piece. The float rides directly on the stock flow providing an annular opening within the tube of such dimensions that a precise dynamic balance is maintained between the effective downward weight of the float and the upward pressure due to fluid velocity. Any change in flow rate tends to alter the velocity pressure and so causes a repositioning of the float in the tube to restore the balance.

The position of the float (flow rate) may be read directly through a glass extension tube, transmitted magnetically to a recording pen, or telemetered electrically or pneumatically to a remote recording instrument. The recording cases may be furnished with totalizing mechanisms to sum up the stock passed in any time interval. Dual recording remote instruments may also be equipped with ratio mechanisms so that an exact proportionality may be automatically maintained between two or more flows.

In a typical application sulphite and groundwood stocks are proportioned to a mixed stock chest in a newsprint mill. The smaller meter, sulphite, is equipped with a manual control valve while the larger groundwood meter has an automatic control valve installed at its discharge. Both flows are telemetered electrically to a remote ratio controller which automatically adjusts the groundwood control valve to maintain the flow in the exact proportion to the sulphite flow set on the ratio dial. Any adjustment of the sulphite manual valve, altering this flow, immediately causes a corresponding change in the groundwood flow, thus maintaining the required proportionality. The flows of sulphite and groundwood are totalized automatically, and a low flow alarm is included, should either flow fall to zero. Multiple proportioning arrangements may be employed when three or more flows are to be blended. In the system described the level of the mixed stock chest sets the proportioning rate by adjusting the flow of sulphite. The sulphite meter telemeters this flow rate pneumatically to each of the several ratio controllers. These instruments each record and control one of the secondary flows, i.e., groundwood, color, etc. Consequently, a rise in mixed stock chest level slows the entire proportioning system and, conversely, a fall in level speeds up the system. Any of the ratio settings may be altered independently of the others.

Another application of the meter is on basis weight control. The two process variables involved in this problem are machine speed and mixed stock flow. The paper machine speed is measured by a pneumatic transmitting tachometer which telemeters the speed measurement to a remote ratio controller. The stock flow is metered by a unit which also telemeters this

G. D. ZIMMERMAN, Fischer & Porter Co., Hatboro, Pa.

value to the ratio controller. Thus both variables are recorded simultaneously on the one chart. The ratio controller maintains the required relationship between these two variables by adjusting a pneumatic control valve in the mixed stock line. Variations in machine speed are compensated for automatically and adjustment of the basis weight setting can be made by simply turning a dial.

One feature of this instrument's performance still under investigation is its inherent consistency compensating tendency. Since the position of the metering float is maintained by a dynamic balance between its effective downward weight and the upward fluid velocity pressure, it follows that any change in the kinetic energy of the fluid will be reflected in the position of the float. Consequently, as the amount of solid material in the slush stock alters, a corresponding deviation in "indicated" flow rate is observed which is quite independent of the "actual" flow rate. The degree of compensation is a factor of float design. At the moment, this property is being investigated with a view to providing a consistency regulator of a radically new design.

To date, these instruments have been installed on numerous stock slurries, both mechanically and chemically pulped, ranging from white water to stock of 4% consistency with almost complete success. Difficulties have been encountered on unknotted stocks, particularly at low flow rates. The diameter of the knots and chips exceeds the dimensions of the annualr opening and so clogs the meter. Another installation precaution is the sizing and location of both manual and automatic control valves, particularly on chemical pulps. An oversized valve has a tendency to filter the stock in a "cracked-open" position. With these exceptions the experience to date demonstrates the ability of this equipment to handle satisfactorily most stock metering problems with the advantages originally expected: lower capital and maintenance costs, elimination of return lines, reduced bulk, completely enclosed in stock line, higher accuracy, permanent records, and greater ease of operation.

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DISCUSSION

Question: Can the regulation of flow of slush stock be held closely?

Answer: The range of error is 1 to 2%. Affecting the range is the accuracy with which we can make calibration tests in a paper mill. The calibration of chests has its own basic accuracy, the determination of consistency has its own limits of error, and these are all taken into account in the percentage accuracy of dead weight measurement.

Question: Have any instruments been tried on proportioning unscreened stock?

Answer: No they haven't; the metering element itself at the zero end of the chart, which is actually 10% of the maximum flow, does not contact the tapering metering tube but it approaches it. The clearance at this point is determined by the maximum particle size of the slurry on which it is to be used. In one instance on unscreened stock in the screen room where screening is not feasible, special equipment is being engineered to handle it by reducing the range and increasing the clearance, and also by increasing the pressure drop on the flow so that the proximity of float in the tube is carried out on as wide a range as possible. There are limitations in this direction.

Question: Are there any problems in fine paper mills using a wide range of pulps?

Answer: The installation of this equipment has been largely in eastern Canada and mainly in dissolving pulp, bleaching, and newsprint plants, however, a fine paper mill has just put in a proportioning unit for krafts, bonds, defibrator stock, rags, and repulped paper. Since this is the first application in the fine paper branch of the industry, these comments should be interpreted as applying more strictly to newsprint and dissolving pulps.

Question: How close can basis weight regulations stay controlled with one of those instruments?

Answer: The basis weight regulation is, of course, no better than the measurement of the machine speed, and we are not in a position to set up accuracy limits on tachometers. Speaking only as an instrument engineer, I would say half of a per cent would be a fair working accuracy limit on that measurement. Then to maintain the mixed stock flow we must again, take into account the accuracy of our equipment and add that error to the measurement of machine speed. We came up with something of the order of 1%. However, that is interpreting only in terms of finite accuracy. Once the equipment is operative and the sheet coming off the end of the line has been accurately determined by the control department and the process variables have settled down, this equipment will then reproduce proportioning between those two variables within an accuracy of 0.1%. That, of course, presupposes uniform stock feed within the limits of 0.3%.

Question: What is the maximum stock consistency that the instrument will handle?

Answer: It has metered 4% stock without any indication it was approaching its upper limit.

Question: Do you have any trouble measuring low-consistency stock?

Answer: Low consistency is a straight forward fluid metering problem and consistency compensation does not come into the picture at all. The tendency for stock of low consistencies, friction-wise, is better than water. Our experience is that the meter will deliver about 1% more stock than it will water, and it develops merely into a volumetric rate of flow instrument.

Question: What is the effect of a 10% variation in freeness?

Answer: We would not be able to detect a 10% change. We have endeavored to check this with the calibration facilities which are available in a paper mill and over quite wide ranges but have been unable to do it. A freeness effect may have been there but it was hidden within the limitations on the calibration run.

Evaluation of Mold-Resisting Treatment of Paper and Paperboard

G. A. CRUICKSHANK

Data are presented which indicate that the agar-plate method commonly used for the evaluation of mold-resisting qualities of paper and paperboard may be unsatisfactory in testing lightweight paper. Changing the paper-to-agar weight ratio in the test can yield results varying in interpretation from that of effective mold-resistance to that of no apparent protection. The choice of the test organism, the pH of the culture medium, and the length of the period of incubation can exert a similar effect upon the interpretation of the test. The various factors are discussed in detail and suggestions are offered for the elimination of the foregoing variables. There appears to be a definite need for a standard testing procedure for the determination of mold-resistance of paper.

THE QUESTION AS to what constitutes adequate mold-resistance is one that has vexed paper manufacturers and laboratory investigators alike for the past several years. In the final analysis the particular purpose for which a paper is intended, and the success or failure of the paper under those conditions of use, should be the deciding factors.

Various tests for the effectiveness of the mold-resisting treatment, designed to simulate actual conditions of use, have been devised. However, as pointed out by Shema (*1*) most of the methods used have been unduly complicated and not well adapted to the routine examination of samples for control purposes.

In a recent paper Shema (*1*) has proposed the use of a simple testing procedure very similar to one described by Thom, Humfield, and Holman (*2*) which has been rather widely used in determining the mildew-resistant qualities of textiles. Shema's method comprises placing a 2-inch square of the paper sample on the surface of an agar medium capable of supporting the growth of molds. The paper surface is then inoculated with 1 ml. of a spore suspension of the test organism, incubated for 2 or 3 weeks and observed for the presence or absence of mold growth on the surface of the paper. The test has the advantages of extreme simplicity and reproducibility. It requires no specialized equipment and is adapted to the testing of a large number of samples by a person of limited training.

EFFECT OF THE AMOUNT OF AGAR IN THE PLATE

Some time ago it was noted that certain samples of pentachlorophenol-treated paper permitted rapid and abundant growth of our test fungi when tested by a modification of Shema's method. Other samples, shown by analysis to contain similar or even smaller amounts of the chlorinated phenol, completely inhibited the growth of the test organisms. In each case the samples which failed to show mold-resistant qualities were thin, lightweight papers such as glassine or soap wrap.

It was considered possible that the method being used, which called for 15 ml. of agar in the plates, might not be satisfactory for the testing of lightweight papers, either by reason of leaching out of the antimycotic agent into the agar or by dilution of the agent with the liquid absorbed into the paper from the agar. In either case it would seem likely that of two papers treated with an equal per cent of antimycotic agent the heavier paper might retain a greater absolute amount of the chemical than the lighter one. To check on this viewpoint the following experiment was set up.

Two-inch squares were cut from a sheet of 25-pound glassine paper, pH 5.35, containing 0.22% pentachlorophenol. A single square was placed in a sterile Petri plate and covered with 15 ml. of Sabouraud's dextrose agar. In other Petri plates the squares were superimposed one over another so that there were plates containing 2, 3, 4, 5, and 6 squares, respectively. To each plate there was then added 15 ml. of the agar so that the piles were covered in each case. The agar was allowed to solidify and then streaked crosswise over the center of the several piles of paper squares with spores from a culture of *Aspergillus versicolor*. The plates were then incubated for 7 days at 30°C. and observed for growth. Figure 1

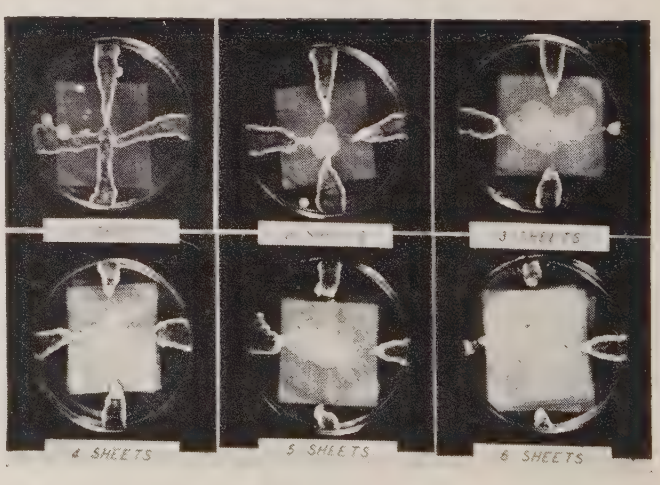

***Fig. 1. Plates cross-streaked with* Aspergillus versicolor**

G. A. CRUICKSHANK, Chief Bacteriologist, National Aluminate Corp., Chicago, Ill.

shows that with a single thickness of the paper growth was obtained along the entire line of inoculation. With two thicknesses the growth tapered in with increasing evidence of inhibition to about $^5/_8$ inch from the edges of the square, leaving a space of about 1 inch in the middle of the square free from growth. With three sheets there was marked inhibition, the growth encroaching over the edges of the square to a maximum of $^3/_8$ inch. The remaining plates showed increasingly better inhibition of growth over the paper.

These findings were further substantiated by a second type of experiment in which single squares of a thin pentachlorophenol-treated paper were placed on the surface of different amounts of agar in Petri plates. A series of five sterile Petri plates was prepared containing, respectively, 5, 10, 15, 20, and 25 ml. of Sabouraud's dextrose agar. Two-inch squares cut from a single sheet were placed on the surface of the agar in each plate and streaked with spores of *Aspergillus niger* in four parallel lines. The plates were incubated in a moist chamber for seven days and examined for growth. Reference to Fig. 2 indicates fairly heavy growth in the plates containing 20 and 25 ml. of agar. The growth was sparse with 15 ml., barely perceptible with 10 ml., and entirely absent with 5 ml. These two experiments indicate that the interpretation of the results obtained with the agar-plate method of testing for mold-resistance of paper depends upon the ratio between the weight of the paper sample and the amount of agar used in the test. It is evident that this factor should be controlled.

Ideally, the 2-inch square should be weighed and the amount of agar to be used should be regulated accordingly. Such a precedure would be time consuming and furthermore it would suggest a refinement in accuracy which actually is not justified since other

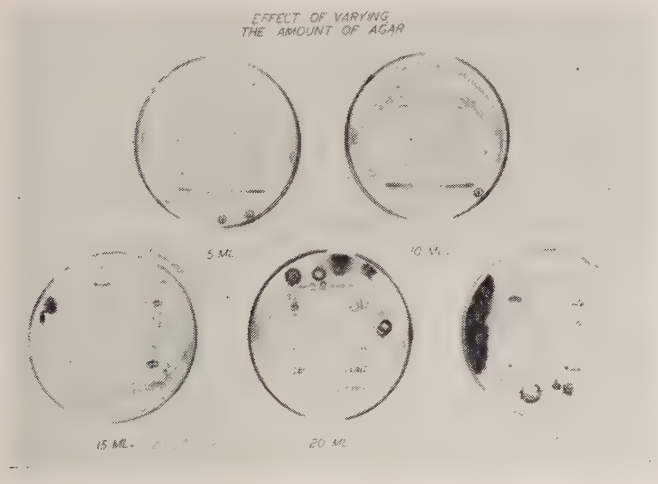

***Fig. 2. Paper streaked with* Aspergillus niger**

factors such as variation in the resistance of the test organism, in incubator humidity, in the culture medium, etc., might well influence the results to a certain extent.

It appeared that the caliper of the paper might possibly serve as a guide to the amount of agar to use, provided it could be shown that a reasonably close relationship exists between the weight and the thickness of various papers. To determine this point 50 random samples of paper and paperboard, coated and uncoated, varying in thickness from 0.0012 to 0.125 inch, were cut accurately into 2-inch squares and the average weight of six such squares determined for each paper. The average thickness of each type was then determined using an ordinary Brown and Sharpe micrometer. Plotting the caliper of the various papers against the corresponding weights of the 2-inch squares showed that the relationship between weight and thickness was essentially a straight line with maximum deviation of approximately 15%.

This correlation between weight and thickness would appear to be sufficiently close for all practical purposes. However, in view of the observed deviation and of the other variables inherent in the method it is suggested that too close an adherence to the ratio of the caliper of the paper to the amount of agar should not be attempted. Since it is not practical to use less than 5 ml. of agar in a Petri plate it is proposed that all papers less than 0.010 inch thick be tested on 5 ml. of agar. The following amounts of agar have given satisfactory results in our laboratory for the papers indicated:

Thickness of paper	*Milliliters of agar in plate*
0.000–0.010	5
0.011–0.015	10
0.016–0.020	15
0.021–0.025	20
0.026–0.030	25
0.031–0.035	30
0.036–0.040	35
0.041 or greater	40

With the smaller amounts of agar such as 5 and 10 ml. there is considerable drying out during incubation. To prevent this, the practice of humidifying the incubator to a point where there are always present visible droplets of moisture on the inner surface of the Petri plate tops was adopted.

EFFECT OF THE pH OF THE CULTURE MEDIUM

It has been shown by Jensen (*3*) and others that the fungus-inhibiting action of pentachlorophenol is very markedly enhanced by moderate increase in acidity. The same was true for phenylmercuric compounds and other well-known fungistatic agents. It would seem reasonable, therefore, to assume that the pH of the culture medium might well affect the interpretation of this method of testing the moldproof qualities of paper.

To test the validity of this assumption the pH of aliquot portions of a single batch of Sabouraud's dextrose agar was adjusted with normal NaOH to cover a pH range extending from pH 5.5 to 8.9. Fifteen milliliters of agar from each portion was measured into each of a series of sterile Petri plates and allowed to solidify. A sample of 0.003-inch soap wrap, pH 4.65, containing 0.16% pentachlorophenol was cut into 2-inch squares and one of the squares was placed on the surface of the agar in each plate. All squares were then heavily inoculated with spores of *A. versicolor* in such a manner as to form four parallel, clearly visible

streaks across each square. A second set of plates, similarly prepared was inoculated in the same way with spores of *A. niger*. All plates were incubated for ten days at 30°C. and observed for growth.

There appeared to be no significant difference in the amount of growth with either test organism at pH levels between pH 6.9 and 8.9. Below pH 6.9, however, there was a progressively decreasing abun-

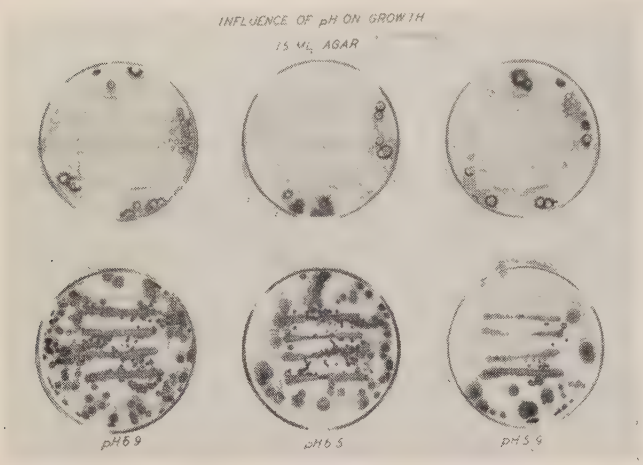

Fig. 3. ***Upper row,*** **Aspergillus niger;** ***Lower row,*** **Aspergillus versicolor**

dance of growth along the streaks. Figure 3 shows that *A. niger* was completely inhibited at pH 5.9 and that the growth of *A. versicolor* was considerably reduced from that shown at pH 6.9.

Since it had previously been shown that the amount of agar used in the test could affect the amount of growth obtained, the foregoing experiment was re-

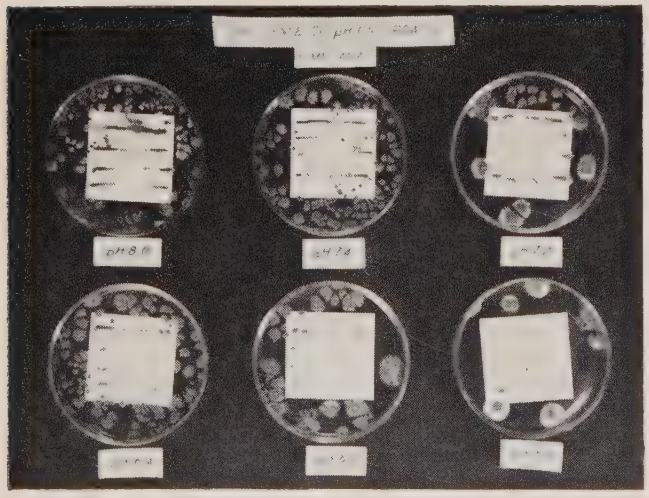

Fig. 4. ***Paper streaked with*** **Aspergillus versicolor**

peated using the same treated 0.003-inch paper in plates containing only 5 ml. of the agar. The plates were streaked as before using *A. versicolor*. Examination of these plates after ten days incubation showed a gradually decreasing amount of growth beginning at pH 8.0 and extending down to pH 5.5. Figure 4 shows that growth throughout the range is considerably less than with 15 ml. of agar.

These experiments would seem to imply that the pH of the culture medium is a factor which should not be overlooked in testing for mold-resistance. Incidentally they also serve to confirm the importance of the amount of culture medium and to illustrate the difference in resistance shown by two common types of mold, thereby emphasizing the importance of using a test organism of adequate resistance. *A. niger* has frequently been used as a criterion for the determination of the effectiveness of antimycotic treatment, yet reference to Fig. 3 clearly shows that *A. versicolor* is able to grow quite well under conditions which completely inhibit growth of *A. niger*.

EFFECT OF THE DURATION OF INCUBATION

It is a common observation in conducting mold-resistance tests by the agar-plate method to note the delayed appearance of colonies of the test organism on the squares of paper. To avoid the possibility of missing this type of growth an incubation period of two to three weeks has been recommended.

In testing paper in intimate contact with agar there is the possibility of a gradual diffusion of some

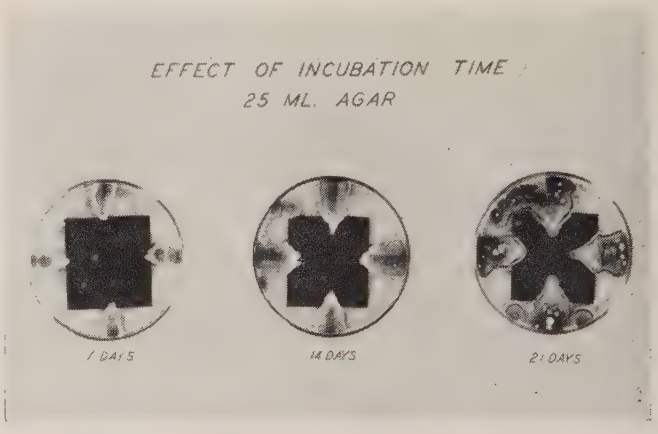

Fig. 5. ***Plates cross-streaked with*** **Aspergillus versicolor**

of the antimycotic agent from the paper into the agar. Obviously the rate of this diffusion will depend upon the concentration of the antimycotic in the paper, being greater when the concentration is greater, but it will also depend upon the solubility of the antimycotic, the more soluble agent showing the higher diffusion rates. This latter consideration would point to the importance of proper mill application of the soluble sodium chlorophenates so that the finished paper will contain the antimycotic substantially in the free phenol form, in which form it is relatively insoluble and most effective. It was considered possible that the development of colonies of the test organism only after prolonged incubation might be explained on the basis of a reduced antimycotic content in the paper due to loss by diffusion.

To test this theory a sample of 0.016 jute liner, pH 6.15, containing 0.50% sodium pentachlorophenate, was cut into 2-inch squares. Twenty-five milliliters of Sabouraud's dextrose agar was placed in each of 18 Petri plates. A similar number of plates containing 15 ml. of the agar was prepared. A square of the paper was placed in the center of each plate and all

plates were streaked crosswise at right angles over the center of the square with spores of *A. versicolor*. All plates were incubated in a moist chamber at 30°C.

At intervals of 7, 14, and 21 days six of the plates in each series were removed from the incubator. The plates from each period of incubation were remarkably uniform in appearance. Figure 5 shows the growth of the test organism on the 25-ml. series. It will be noted that the growth encroaches over the paper more and more with increasing length of the period of incubation. A similar overgrowth of the edges of the paper occurred on the plates containing 15 ml. of agar but the extent of the encroachment over the paper was uniformly less than with 25 ml.

At the end of seven days pentachlorophenol was present in the agar from the 25-ml. series but could not be detected in the 15-ml. series. Analysis of the 25-ml. series after 14 days showed an increase in the amount of pentachlorophenol present. A further increase was apparent at the end of 21 days, indicating a slow diffusion of the chemical from the paper. This is further supported by the progressive encroachment of the growth toward the center of the square. It seems probable then that delayed growth appearing on the paper several days after heavy, normal growth has been established in the rest of the plate may be due to a lowering of the original content of antimycotic in the paper due to leaching.

DISCUSSION

Unquestionably, there is a need in the paper industry for a satisfactory standard method of determining the mold resistance of different types of paper and paperboard on a comparable basis. It might be assumed that if a certain sample of paper is adequately mold-resistant, any other sample in which the per cent of antimycotic and the pH are identical with the first sample will also be adequately mold-resistant. This is probably true insofar as the actual papers are concerned, but very questionable under the variety of conditions that may be encountered in practical use. Failure of a supposedly mold-resistant paper in use is undoubtedly due in many cases to the same factors which affect the laboratory test, specifically lowering of the antimycotic content through diffusion or dilution, changing the pH of the paper, encountering a mold of especially high resistance, and the duration of contact with the packaged material. Whatever the test used in the laboratory, it would be desirable that the results be translatable into the requirements of a variety of commercial uses.

The employment of a relatively constant agar-to-paper ratio in the agar-plate method would seem to offer a method of grading the antimycotic properties of paper on the basis of service requirements. Take, for example, a 0.005-inch paper which in itself is found to be mold-resistant when tested on 5 ml. of agar. Let it be assumed that in most uses this paper gives satisfactory service. However, where service conditions are unusually severe and the paper fails to stand up, it is evident that a higher antimycotic content is necessary. In such a case the laboratory test should be increased in severity to a point which would indicate mold-resistance of a degree sufficient to meet the severe service condition. This would be done by increasing the amount of agar used in the test from the normal 5 ml. to 10 or even 15 ml. Once the standard requirement for the particular service use is established, future laboratory tests would be conducted employing the appropriate amount of agar for that use.

In selecting an appropriate agar medium for use in this test the principal factor to be considered is the ability of the medium to support a rapid and abundant growth of the test organism. One such medium found to be satisfactory is Sabouraud's dextrose agar (Difco). It is a uniform, adequately buffered medium providing rapid, luxuriant growth of a wide variety of molds.

The pH of the agar medium has been shown to exert an appreciable effect on the results obtained with this method. It would be desirable to use a medium adjusted to a pH identical with that of the paper being tested. This, of course, would be highly impractical. However, since present day antimycotic treatment in the paper industry is largely confined to the use of chlorinated phenols and since these materials are most effectively applied under acid conditions, the use of an acid medium is recommended. One having a reaction of pH 5.5 to 5.6 is suggested as an average value for pentachlorophenol-treated papers. Sabouraud's agar provides such a pH level.

The length of the period of incubation, usually two to three weeks, might be considerably reduced without detracting from the value of the test provided that the ratio of the weight of paper to the weight of agar is kept relatively constant. Any period of incubation we may choose is distinctly arbitrary in nature and since results of the test are apparently influenced appreciably by diffusion of the chemical from the paper, it is proposed that the incubation period be reduced to approximately twice the time required for normal growth and sporulation of the test organism on the culture medium. Using Sabouraud's agar an incubation period of seven days appears to be both convenient and satisfactory. It must be understood, of course, that no comparison can be made between results obtained using a seven-day period and those using a 21-day period. However, comparison of different papers using the seven-day period would appear to be just as valid as similar comparisons using the 21-day period.

The method of inoculating the paper by spreading 1 ml. of a spore suspension of the test organisms over the surface of the test square of paper does not appear to be satisfactory for the same reason that a constant amount of agar is not satisfactory in testing papers of different weight. The leaching effect of 1 ml. of suspension on a thin sheet would be much greater than on a heavy paper or paperboard. Consequently it is suggested that inoculation of the paper be made directly from an agar culture of the test mold using a bent inoculating needle. This may be done by simply spreading the spores over the paper with the bent wire However, a method developed in the course of this work seems to offer certain advantages. This method consists in streaking the spores in one line diametrically across the center of the test square from the perimeter of the Petri plate, then picking up a second

inoculum of spores from the mold culture and streaking a second line across the plate at right angles to the first. By this method it is often possible to detect an excessive amount of antimycotic in the paper since growth in such a case is inhibited not only on the paper itself but may also be inhibited along the lines of inoculation on the agar beyond the edges of the paper.

The choice of an appropriate test organism is a very important factor in any test of this type and is one that should not be made on the basis of the limited information presently available. Many of the molds are completely inhibited by the presence of bacterial growth on the paper. Others, like *Chaetomium globosum* and *A. niger* are not affected to any extent by the presence of bacteria. However, these microorganisms are by no means the most resistant types available. A study of the relative merits of different molds for the purpose of choosing one or more strains of appropriate characteristics would appear to be in order.

CONCLUSIONS

1. In the agar-plate method of testing the antimycotic properties of paper the measure of apparent mold-resistance depends upon the following factors: (a) the ratio between the weight of the paper sample and the amount of agar used in the test, (b) the pH of the agar, (c) the resistance of the test organism, and (d) the length of the incubation period.

2. All of these factors can be and should be controlled.

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Influence of Resin Bonds on the Water Immersion Stability of Paper Base Laminates

M. P. SEIDEL

The weight and volume changes which occur as a result of the water immersion of kraft paper base phenolic resin bonded laminates have been studied. These changes are relatively independent of molding temperatures in the range of 150 to 180°C. but are markedly influenced by resin condensation catalyst.

The widespread use of paper base laminates for decorative and functional applications has spurred the development of more suitable laminating papers and resins. Phenolic resin development received considerable impetus by the commercial introduction of high-purity synthetic phenol during the decade following the first world war. Although the resin bond ordinarily accounts for less than half of the total weight of a paper-base phenolic resin laminate, only the resin contributes moisture resistance and compression strength to the union. The principal contributions of the paper to the paper-resin composite are flexural, impact, and tensile strength. The present paper is confined to the behavior of a plurality of resins and a single paper, but other studies in which laminates are made from a number of papers and a single resin are now in progress and will form the basis of subsequent reports.

Although phenolic resins of commercial importance were being developed by Leo Baekeland as early as 1909 the art has always managed to pace the science in this field. The more fundamental aspects of phenolic resin technology are not being entirely ignored however, for a continuous stream of papers on structure and mechanism are being published by Bender in America, Redfarn in England, von Euler in Sweden, and Hultzch and Zinke in Germany.

M. P. Seidel, Chem. Dept., Research Lab., Westinghouse Electric Corp., East Pittsburgh, Pa.

PREPARATION OF RESIN

The varnishes which were used in this study were prepared by a standard technique—the catalyst was the only variable. A mixture of phenol and formaldehyde in a mole ratio of slightly less than unity was charged into a 5-gallon stainless steel, steam-heated kettle. To this mixture was added a small quantity of the catalyst and the mixture was refluxed while being vigorously stirred. At the conclusion of the reflux period vacuum was applied to the system and all volatile compounds which boiled below 100°C. (pressure of 10 mm. of mercury) were removed. The resin was chilled by the addition of a sufficient amount of an alcohol-water mixture to give a varnish which contained about 50% "solids." The common properties which are measured on phenolic laminating varnishes are defined in Table I. Values obtained for the varnishes used in this study are given in Table II.

Table I

Poly time:	The time necessary to gel a 20-gram sample of the resin at 150°C.
Recoverable solids:	The percentage residue remaining after a 1.5-gram sample of the resin has been heated with 15 grams of dry sand for 2 hours at 170°C.
Viscosity:	Measured by means of Mac Michael viscosimeter, Gardener-Holt bubble tubes, Demmler cup, or falling ball viscosimeter.
Water tolerance:	A 10.0-gram sample of resin is titrated with water until a permanent cloud is produced.

Table II

Resin	Solids, %	Viscosity, poises	Water Compatibility, %	Poly time (min. 150°C.)
Ethylene diamine catalyzed	49.8	1.33	6.1	10.8
$Sr(OH)_2$ catalyzed	45.5	0.38	36.3	11.0
$Ca(OH)_2$ catalyzed	47.3	1.08	28.6	8.6
$Ba(OH)_2$ catalyzed	49.4	0.97	27.2	9.0
NaOH catalyzed	68.2	1.47	....	6.3

THE FILLER

The paper used in making these boards was a special water absorbent kraft paper. The principal properties of this paper are tabulated in Table III.

Table III. Properties of Kraft Paper

Thickness: 0.010 inch
Air resistance: 4–7 seconds per 100 cc (Gurley densometer)
Bursting strength: 50 lb.
Density: 3.15 grams per 6-inch square
Ash: 1%
Moisture: 6%

PAPER TREATING

The paper was treated in a 10-foot semiautomatic horizontal treating machine. In this machine the paper is automatically unwound from the roll, passed

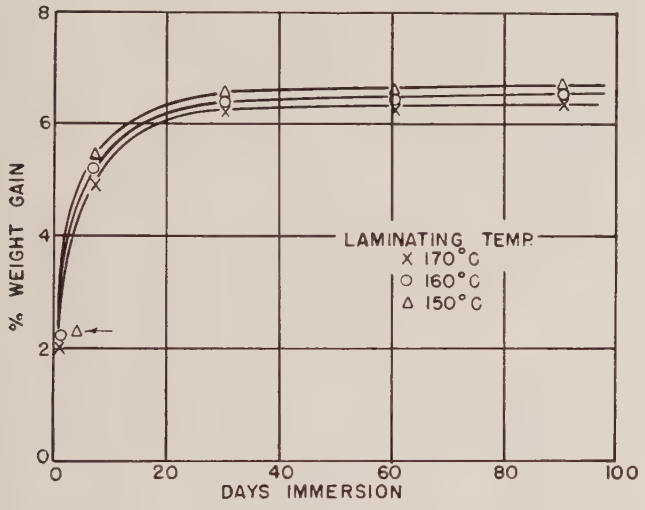

Fig. 1. Moisture sorption of phenolic laminates

through a varnish tank, and then through adjustable squeeze rolls. The wet sheet is supported on stainless steel "sticks" which are affixed to a continuous chain conveyor which passes through the indirectly heated forced air oven. "Nip" rolls at the far end of the oven lift the treated material from the conveyor and feed it through a constant tension rewind device. Process variables which can be controlled over wide ranges in this machine are web velocity, air temperature, air velocity, air direction, web tension, and web resin content.

Speed adjustments at various stations in the treating process are necessary because the web expands when wet by the varnish and shrinks because of the reduction in "tack." Judicious adjustment of these several

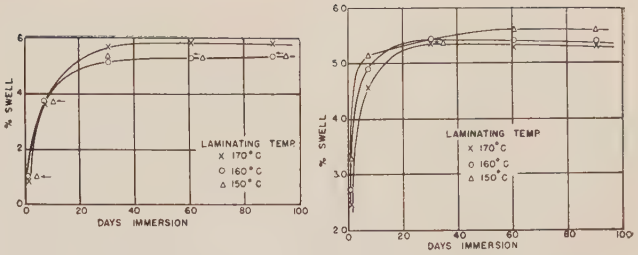

Fig. 2 (left). Center swelling of phenolic laminates
Fig. 3 (right). Edge swelling of phenolic laminates

variables permits material to be treated to narrow limits within a wide range of greenness, volatility, and ratio. These terms are defined in Table IV.

BODY STOCK AND SURFACE STOCK

In general the core stock of paper base laminates differs from the surface stock in several respects. Surface stock has a high ratio and high greenness in order

Table IV

Greenness: The percentage weight loss which occurs when a 10 to 15-gram board is made by laminating a stack of treated material for 5 minutes at 170°C. and 1000 p.s.i.
Volatility: The percentage weight loss which occurs when a single sheet of treated material is heated for 15 minutes at 115°C. in a forced draft oven.
Ratio: The weight ratio of a given area of treated material to an identical area of base material.

to impart high gloss to the board and also to reduce the incidence toward pitting and sticking to the press plates. Core stock has a lower ratio and greenness to lessen brittleness and excessive lateral movement of the stack while the latter is under pressure.

LAMINATING

The boards which were used in the present study were made by stacking ten pieces of treated material (two surface and eight body) between flat mirror finish stainless steel press plates. These plates were backed by cushions of untreated paper to equalize pressure on the treated material and the entire assemblage was placed between the platens of a steam-heated hydraulic press. The press was closed to a pressure of 1000 p.s.i., steam was admitted until the temperature of the platen buried thermocouple had reached a predetermined temperature (150 to 180°C.) and the stack was held under these conditions until it was thoroughly cured (20 to 40 minutes). The board was cooled to room temperature by the admission of cooling water to the platens after which the press was opened and the board removed.

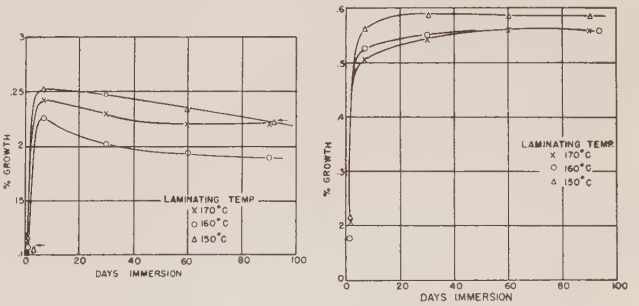

Fig. 4 (left). With grain growth of phenolic laminates
Fig. 5 (right). Cross grain growth of phenolic laminates

TESTING

The boards were cut into test specimens by means of a high-speed water cooled carborundum cut-off disk. The tests which are to be reported at this time are moisture absorption, center swelling, edge swelling, and growth (with paper grain and across paper grain). The first three tests are run on a 1 by 3-inch sample; the growth tests are run on a 5.5 by 0.5-inch sample. All values which are given in the accompanying figures are the average of three separate determinations. The test pieces were wholly edge immersed in water at room temperature and were removed only for the short time that was required to weigh or measure them. Linear changes were followed by measuring the length or thickness of the pieces by means of rigidly mounted dial indicators that were direct reading to 0.0001 inch and weight changes were followed by means of an analytical balance. No corrections were applied for water extractable materials.

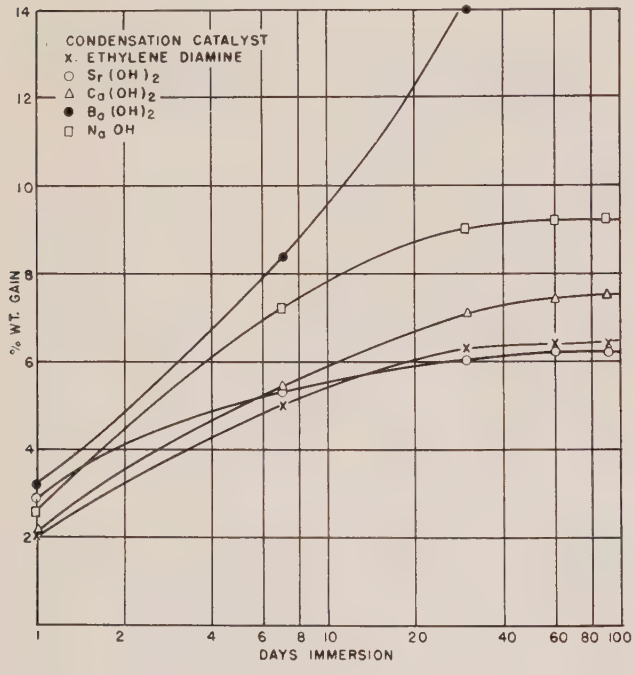

Fig. 6. Moisture sorption of phenolic laminates

In Table V the individual test values for a given set of samples are given as a function of the immersion time. This table illustrates the reproducibility of the data. The row headed "max." is the maximum value observed for the set of three samples; the row "min." is the minimum value; the row headed "dev." is the arithmetic difference between the maximum and minimum values; and "av." is the arithmetic average of the three values. Inspection of the figures reported shows that the deviation in a single set of three samples is of the order of 5 to 10% of the averages reported for the three samples. These data indicate that the rate of water penetration parallel to the laminations is much greater than that normal to the laminations. This conclusion is based on a comparison of the edge swell and center swell. Another point of interest is the effect of fiber orientation in the paper on the hydrophilic character of the board. Thus the growth normal to the grain (machine direction) of the paper is about twice as great as is the growth parallel to the grain.

Table V. Phenolic Bonded Kraft Paper Micarta

Percentage Increase on Water Immersion
(Initial Thickness: 0.0760 Inch)

Days	1	7	30	60	90
			Moisture Absorption		
Max.	2.08	5.07	6.38	6.48	6.56
Min.	1.97	4.89	6.19	6.31	6 37
Dev.	0.11	0.18	0.19	0.17	0 19
Av.	2.03	4.98	6.29	6.40	6 48
			Center Swelling		
Max.	1.06	3.83	5.94	6.21	5 94
Min.	0.39	3.49	5.56	5.56	5 17
Dev.	0.67	0.34	0.38	0.65	0.77
Av.	0.83	3.65	5.70	5.87	5.61
			Edge Swelling		
Max.	2.92	4.79	5.72	5.05	5.85
Min.	1.81	4.44	4.94	4.56	4.82
Dev.	1.11	0.35	0.78	0.49	1.03
Av.	2.46	4.59	5.36	4.89	5.32
			Growth (with Paper Grain)		
Max.	0.136	0.244	0.232	0.243	0.243
Min.	0.094	0.232	0.217	0.209	0.207
Dev.	0.042	0.012	0.015	0.034	0.036
Av.	0.112	0.239	0.227	0.222	0.222
			Growth (Across Paper Grain)		
Max.	0.219	0.558	0.564	0.571	0.572
Min.	0.207	0.516	0.513	0.550	0.538
Dev.	0.012	0.042	0.051	0.021	0.034
Av.	0.213	0.539	0.544	0.561	0.560

In Figs. 1 to 5 the laminating temperature dependence of the moisture immersion properties is illustrated. The boards were held at the higher temperature for 20 minutes and at the two lower temperatures for 40 minutes. An examination of these curves seems to indicate that the moisture properties of the boards are independent of the laminating temperature as long as the time-temperature relationships are such that the boards are well cured. More complete data than those which are presented here have verified this conclusion. The maxima exhibited by the growth samples

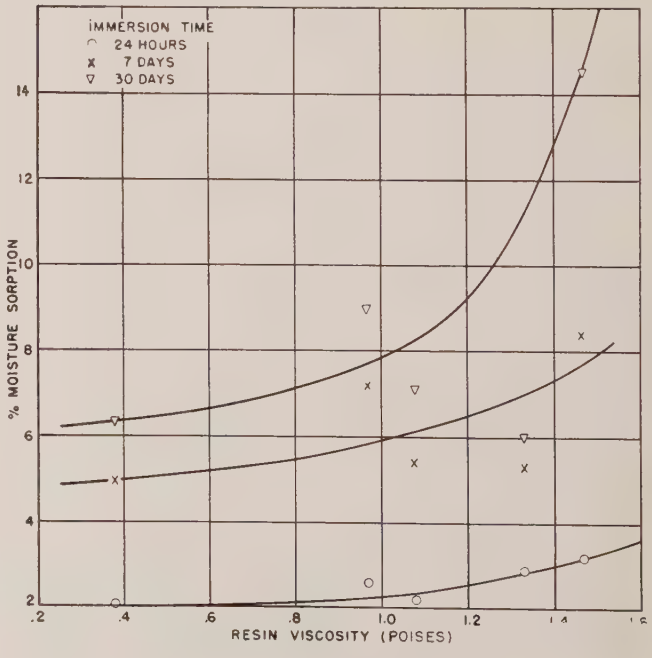

Fig. 7. The paper wettability of phenolic resins

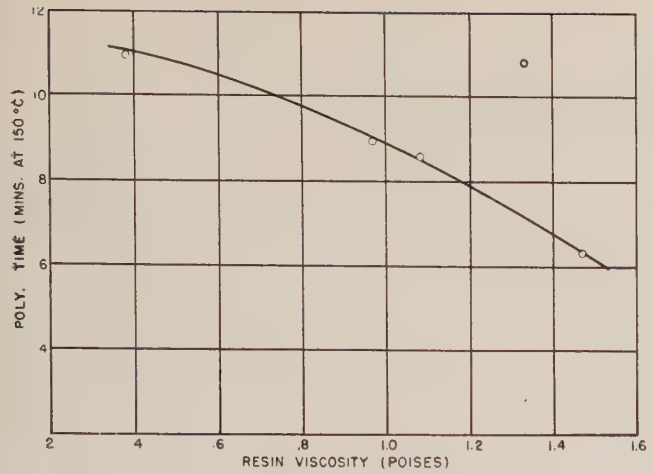

Fig. 8. Phenolic resin reactivity

in Fig. 4 are real but we have no explanation for this phenomenon at this time.

In Fig. 6 the moisture sorption of the several systems which were studied is illustrated. Although the relative spread among the boards is only about 1% after 24 hours immersion this dispersion rises to 3% after 7 days immersion. Inasmuch as the moisture sorption of phenolic resins is only about 0.2% at room temperature (24-hour immersion) the higher values shown in Fig. 6 must be associated with the paper. Macroscopic examination of the treated paper and the boards fails to disclose any inhomogeneity hence the differences shown in the moisture sorption curves must be due to degree of resin dispersion in the paper fiber structure itself. Such differences might well be due to differences in the average molecular weight or the molecular weight distribution of the several resins. If the moisture sorption is plotted as a function of the resin solution viscosity, as in Fig. 7, it is found that a rough correlation is obtained particularly at the 24 hour immersion values. Although the viscosity determinations made on these resins lack many refinements the values reported are a function of the molecular weight. This curve shows that resins of low viscosity (average molecular weight) penetrate the paper fiber structure more readily than do those of higher molecular weight.

Another useful function of resin solution viscosity for a family of resins of similar structure is the correlation with poly time at 150°C. As indicated in Fig. 8 resins of high viscosity have low poly time. The point displaced from the curve is for the ethylene diamine catalyzed resin and the suggestion has been made that this resin differs structurally from the others. Such curves might be useful as classification aids in a fundamental study of phenolic resins.

In Fig. 9 the center swelling of the various boards has been plotted as a function of immersion time. Volume swelling like moisture sorption is associated with the hydrophylic character of the cellulose rather than the swelling of the resin itself. As was noted in Fig. 6 moisture sorption values tend to level off after long immersion times. Some of the points appearing in Fig. 9 are replotted in Fig. 10 to show the relative values for the two types of swelling. The higher values for the edge swelling indicate that water is able to penetrate the boards more easily parallel to the laminations than normal to the laminations. The swelling characteristics of the boards vary with the resin solution viscosity in a fashion similar to that shown by the moisture sorption. This fact is to be expected when the curves in Fig. 11 are examined. These curves indicate the lack of linear dependence of swelling on moisture sorption. The relative rates of edge and center swelling are indicated and the greater range of edge penetration of moisture over center penetration which has been previously noted is again demonstrated.

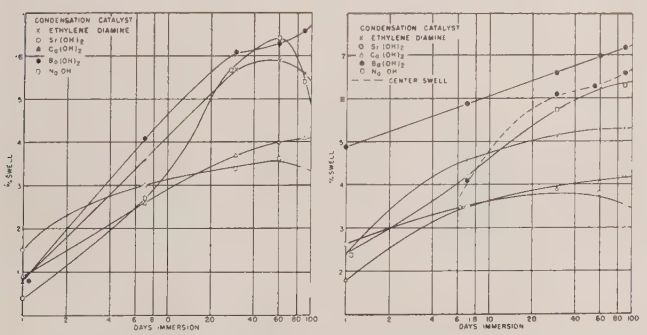

Fig. 9 (left). Center swelling of phenolic laminates
Fig. 10 (right). Edge swelling of phenolic laminates

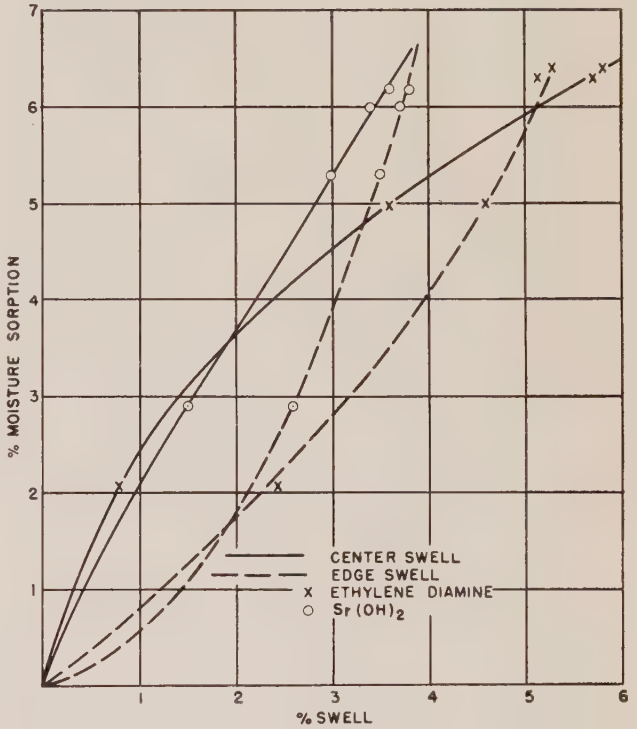

Fig. 11. Moisture weight—thickness function of phenolic laminates

In conclusion it can be said that:

1. The moisture dimensional properties of well-bonded boards are independent of the laminating temperature.
2. Correlations have been found between resin solution viscosity and moisture dimensional properties.
3. The alkaline earth bases produce resins of differing paper bonding character.

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Instruments and Controls

Factors in Their Selection

HAROLD A. SHOLL

Paper mill instrumentation has progressed from the experimental stage to a condition of certainty for most applications. However, standardized procedures cannot be prescribed for the majority of instrument control uses because few processes are identical. Instrument and control selection can be based on experience gained by mill men and instrument engineers from similar installations, but this serves only as a starting point. Factors paramount to one application may be relatively unimportant or completely absent from another so that previous application experience must be backed up by a thorough engineering study of the problem at hand. Determination of all variables and required results may indicate the need for elaborate cascade control, in one case, or in other cases, a simple inexpensive controller. The complete analysis of each control application makes possible accurate prediction of process results to be expected from the expenditure for instrumentation, thus more confidently justifying such expenditures to management.

THE SELECTION of instruments and controls for a pulp or paper mill deserves as much thought and attention as the selection of mill process equipment. It deserves this thought and attention because in most instances process equipment will function properly only if correctly controlled, and with the modern high-speed continuous processing methods now in use adequate control is attainable only through the intelligent application of carefully engineered instrumentation and automatic control.

It is no longer sufficient to specify a certain system of instrumentation merely because another mill is using this system on a similar application. Slight variations in processing methods, operating technique, and end product may cause the control system, which is performing satisfactorily at one mill, to produce mediocre or poor results at another.

Instrument manufacturers retain staffs of skilled engineers thoroughly familiar with the capabilities and limitations of various industrial instruments and controls. Since their prime function is to make studies of pertinent process variables and results desired, and to recommend systems of instrumentation which will produce these results, it is to the advantage of mill operators to consult with these specialists on problems of instrumentation and assure themselves that any measuring or control systems installed will produce the greatest economic advantage to the mill.

The question of indicator versus recorder is typical of a factor frequently given little or no consideration in selecting an instrument. Too frequently the need for a recorder is taken for granted in spite of the increased initial cost and the cost of additional charts. When the process is such that a continuous chart record aids the operator in observing the trend of an important variable or when this record supplies helpful information concerning the time and degree of process fluctuations, the choice of a recording instrument is economically justified. Measurement of digester temperatures and pressures are excellent examples of applications where continuous recording is highly desirable.

There are, however, many places in the mill where indicating instruments are adequate. Measurement of stock chest level could be such an application. In this case, immediate knowledge of the level within the chest is of interest to the operator, and he would derive no particular benefit from a record showing the levels that existed three or four hours ago.

There is, however, no hard and fast rule for determining when an indicator should or should not be used. As mentioned previously, slight variations in processing methods and operating techniques make it necessary to judge each application on its own merits. In one mill, for example, an indication of liquid level in the beaters may be deemed adequate, while in another a record is considered necessary to serve as a daily production record of the output of each beater.

SELECTION OF LIQUID LEVEL INSTRUMENT

Measurement and control of a fluid in a tank or chest is normally considered a very simple instrument application. Requests for quotations are actually received in which no mention is made of the process conditions or the tolerances which must be maintained. Obviously, a system of instrumentation recommended blindly as the result of such a request has a better than even chance of performing indifferently when installed. It may be helpful to list a few of the methods of measuring and controlling liquid level and briefly discussing the capabilities and limitations of each.

Gage Glasses

When neither record nor automatic control is required, the simple gage glass should not be overlooked as a possibility. Inexpensive and requiring practically no maintenance, this device is practicable when the level involved is not critical and when it varies but slightly over a long period of time. Some limitations are: inconvenience (the operator must go to the gage to observe the level), not adaptable to fluids which can cause clogging, must be observed at regular intervals, and must be located directly on the tank or container which is often located some distance from the operator.

Float Operated Device

When no record is required but when indication

HAROLD A. SHOLL, Member TAPPI; Paper Industry Engineer, Brown Instruments Division, Minneapolis-Honeywell Regulator Co., Philadelphia, Pa.

and/or control is needed, a float-operated device can often be used. The chief advantage here is the low cost since such indicators or controllers can usually be made from material already available at the mill. They are readable from a slightly greater distance than a gage glass and are more convenient to the operator. They are adaptable to a coarse type of control (usually as protection against overflowing or complete emptying of the tank) by means of limit switches which are operated by float movement and actuate pump motors, valves, or signaling devices.

Some of the limitations are: possibility of failure caused by floats or pulleys sticking or jamming, inability to provide close control because of friction and inertia inherent in system, inconvenience (they must be located directly on the tank or container), and lack of adaptability to fluids which would tend to coat or build up a deposit on the float.

Electrode Type Level Controller

When fluids are electrically conductive, these controllers provide an inexpensive reliable and easily maintained method of automatically holding level within preset limits. A low-voltage high-impedance circuit is used to eliminate any possibility of arcing or shock. Two electrodes are normally employed, adjusted to slightly different levels in order to compensate for any foaming or splashing within the tank as shown in Fig. 1. When desired, this differential can be widened to determine the high and low limits of the controlled level. When the fluid touches the upper electrode, a relay functions to stop a pump motor, close a valve, actuate a signaling device, or any combination of the three. When the fluid drops below the lower electrode, the electrical circuit is broken and reverse control action takes place. Although the system is electrical, the addition of electric-pneumatic relays permits its use with pneumatically operated diaphragm motor valves.

When used with fluids which tend to stick or build up on the electrodes, periodic cleaning of the electrodes is necessary. This, to a certain extent, limits the use of the system to open tanks or vats where cleaning of the electrodes will not necessitate the shutting down of a process and excessive maintenance time.

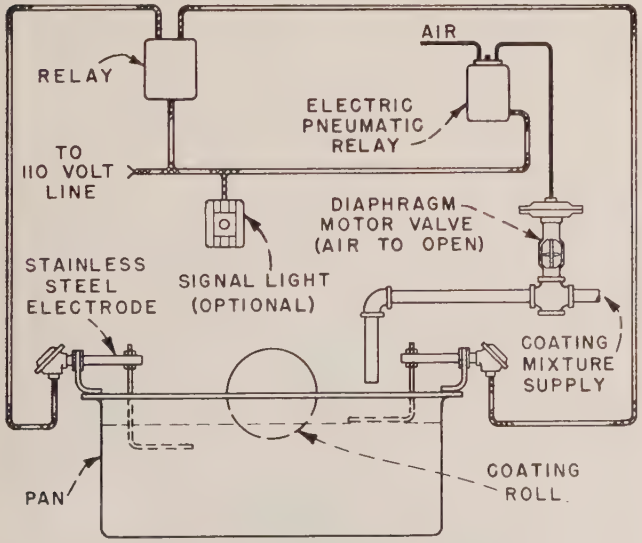


Fig. 1. Electrode-type level control system on paper coating machine

Nonindicating Controllers

These devices offer more refined control than those so far listed. They consist of bellows-type measuring systems which actuate electric or pneumatic control units. Knobs or screws permit adjustment of the set points to the desired values. Closer control is possible since the controllers supply proportional action, i.e., movement of the control valve which is proportional to the amount of deviation of the level from the preset value.

Operation of these controllers is based upon the pressure exerted by the hydraulic head of the measured liquid. When the liquid is nonclogging or noncorrosive, the connecting piping from the device can be tapped directly into the tank or container at the point of minimum level. With other liquids, a diaphragm or an air or water purge prevents the measured fluid from entering the bellows unit. These controllers are available in a number of ranges from 2½ feet to as great a head as may be required.

Since their action depends upon the pressure exerted by a hydraulic head of liquids, they cannot be used for the measurement of levels in tanks under fluctuating pressures or vacuums.

Air Purge-Type Indicators and Recorders

In the field of indicating and recording, the air purge-type liquid level system is probably the most widely used throughout the mill. A small flow of compressed air is bubbled continuously into the measured fluid at the point of minimum level, and the pressure required to force bubbles into the fluid, which pressure is proportional to the height of the liquid above the point of air admission, is accurately measured by an instrument calibrated in liquid level units. In cases where the admission of air to the measured fluid may be objectionable, water or other liquid can be used as the purging medium.

Remote location and a high degree of accuracy are two advantages of this method of measurement. Extremely accurate and sensitive operation can be obtained with the indicating or recording instrument up to 200 feet from the point of measurement. Beyond this, the friction effect in the connecting air piping tends to decrease the sensitivity of the instrument slightly and it is advisable to go to pneumatic transmission. This method, wherein the measuring instrument is located adjacent to the point of measurement and transmits its readings pneumatically to a recording receiver, makes it possible to mount the latter instrument up to 500 feet away and still obtain rapid and accurate indication of the smallest variation in liquid level.

In some instances, friction effect can be disregarded and the instrument located an appreciable distance from the point of measurement without resorting to pneumatic transmission. This is true in the case of a large capacity chest or tank whose level changes slowly and where measuring lag is of relatively little importance. At one paper company, for example, an air purge system is operating successfully with the recording instrument mounted in the bleach plant, over 1600 feet from the regulated stock tank whose level is being measured. Here the capacity of the tank

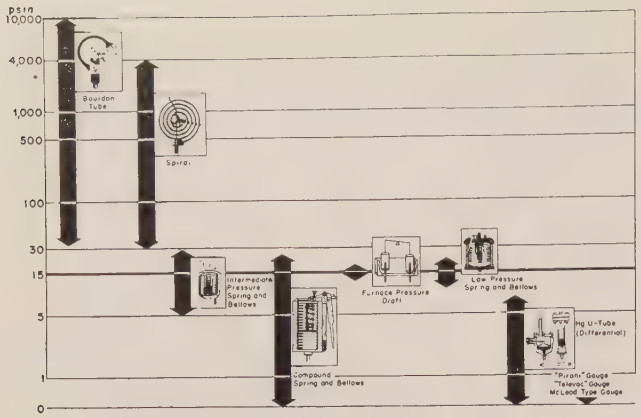


Fig. 2. Measuring elements available for various pressure ranges

is so large and its level changes so slowly that the friction effect of the long run of connecting tubing has little or no significance.

Liquid level instruments of the air purge type can be obtained either as indicators or recorders and are available with electric or pneumatic control. The latter type of control can be supplied in the on-off, proportional, or proportional-plus-reset form.

There is one particularly noteworthy advantage of this method of measuring liquid level. The indicator or recorder is essentially a pressure measuring instrument. During the past few years, special pressure-sensitive elements have been designed to provide accurate, sensitive measurement in every pressure range. These elements, shown in Fig. 2, range from large bellows (used for pressure of a few inches of water) to rugged spirals (for pressures in excess of 4000 p.s.i.). This means that regardless of the hydraulic head of liquid involved in any liquid level application, an instrument with adequate pen torque is available. The net result, of course, is a system that is sensitive to the slightest changes in level and which will indicate or record these changes accurately and continuously. Lacking these specially designed measuring elements, it was not uncommon for an instrument pen or pointer to remain unchanged while the level actually varied plus or minus 5%. This situation was especially objectionable when the instrument was a controller since the control unit was actuated by movement of the pen or pointer.

Since the air purge method of measurement operates on the same principle as the nonindicating controllers previously discussed, it is subject to the same restriction, i.e., it is not applicable to tanks or vessels which are under fluctuating pressures or vacuum.

Differential Pressure Type Measuring Systems

For the measurement of liquid level in tanks or containers under pressures other than atmospheric, this system must be used. It is essentially a meter body such as is used in flow measurement, and an indicating or recording instrument. The low pressure side of the meter body is tapped into the tank at or near the top as shown by Fig. 3, while the high-pressure side is connected to the tank at the point of minimum level. Since both the high- and low-pressure taps are affected equally by any pressure variations occurring within the tank, float movement within the meter body, and consequently movement of the instrument pen or pointer will take place only when the liquid level changes. When the measured fluid is highly corrosive or likely to clog the connecting piping or the meter body, air or water purges are employed.

Mechanical or electric type meter bodies are available. With the former, the indicating or recording instrument is mounted integrally with the meter body and must of necessity be located fairly near the point of measurement. Remote location of the recorder can be obtained, however, by employing pneumatic transmission as described under air purge-type indicators and recorders. With the electric type, the instrument is entirely separate from the meter body and is connected to it by means of a three-wire copper conductor. In this case, the instrument can be placed any distance from the meter body.

Both instruments are available with on-off, proportional proportional-plus-reset control. Typical applications are: measurement of level in sulphite digesters; and measurement of level of first stage liquor storage tank in a brown stock washing system.

Temperature Method of Liquid Level Control

Although seldom thought of as liquid level controllers, thermometer controllers are at times employed for this purpose when a temperature difference exists between two surfaces concerned. Level in a disk or cascade evaporator, for example, is automatically maintained at the correct value by a thermometer controller having its temperature-sensitive bulb mounted at the desired level in the flow chamber. When the hot-black liquor falls below the required level, the bulb senses a drop in temperature and the instrument functions to open a valve controlling liquor

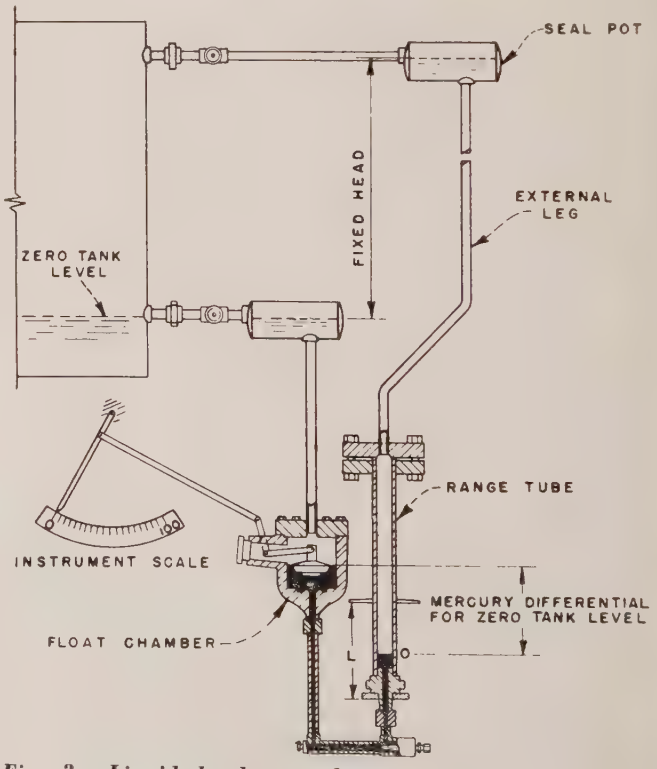


Fig. 3. Liquid level control system for vessels under pressure

feed to the evaporator. As soon as the hot liquor contacts the bulb, the temperature increase causes the control instrument to close the liquor feed valve.

A rather unusual form of liquid-level control, perhaps, but one that should be considered whenever the temperature of the measured fluid is materially above or below that of the surrounding air.

Ray Detection—Type Control

Occasionally, the liquid-level problems arise which cannot be handled by any of the methods discussed.

Examples of such problems are: (1) measurement of the level of very high-density stock in bleaching or reaction-towers; and (2) level measurement of liquid level of chlorine in storage tanks. In the first instance, the difficulty arises from the fact that the stock does not present sufficiently homogenous mass to actuate any of the devices heretofore mentioned. In the latter, local ordinances often prohibit the tank connections necessary for the use of conventional liquid-level measuring systems.

For applications of this type, where cost is not an essential factor, the Gagetron supplies the answer. This device consists of a gamma ray source composed of a small iridium-platinum needle containing a minute amount of a commercially available radium salt (the gamma ray source can be placed outside the tank or container, or inside mounted in a highly corrosive resistant float); a gamma ray detector (a counter of the Geiger-Mueller type); and an electronic recorder or recording controller. Since the gamma ray absorption factor of the vessel is a constant and since the absorption of the gas, air, or vapor above the fluid is negligible, the amount of detected gamma radiation in inversely proportional to the square of the distance between the gamma ray source and the detector. This, of course, is the principle involved when the gamma ray source is inside a float located in the tank or vessel. In the case of the high-density stock in the bleach tower, the gamma ray source is located inside the tower and at the point of minimum level, while the detector is mounted on the other side of the tower and at the point of maximum level. Thus the rays take a diagonal course up and across the tower and the amount of rays detected will bear a distinct relationship to the amount of stock through which they pass. This in turn depends on the level of the stock within the tower.

SELECTION OF PROPER CONTROL ACTION

After having carefully considered all arguments for and against the previously discussed methods of measuring liquid level, assume that a decision has been made to employ an air purge system of measuring; that a record is desirable; and that automatic control is justified. It now becomes necessary to specify which form of control will best tie in with the characteristics of the process involved.

Since a record has been specified, float operated high- and low-limit switches can be eliminated from consideration since it can logically be assumed that they will not provide sufficiently close control.

First, a choice must be made between electric or pneumatic control. In most cases, either type can be supplied in a form suitable for any established set of process characteristics. In general, pneumatic control is preferred by mills so we will make the additional assumption that this type of control is elected.

It must now be decided whether on-off proportional, or proportional-plus-reset control will best produce the desired result. If the process has an excessive lag, rate action should be considered. If level must be controlled with reference to a set time relationship, a time-pattern transmitter is the answer.

There is too frequently a tendency on the part of the prospective instrument user to assume that the most expensive type of control, and, therefore, the most complex, must of necessity provide the best control. Unfortunately, such is not the case, and there are numerous processes which function perfectly under on-off or simple proportional control, but which would be seriously upset by the addition of proportional-plus-reset and rate action. Each process should be judged on its own merits and that form of control selected which is best suited to the inherent process characteristics.

On-Off Control

On-off control is in many cases adequate. This is especially true if the measuring instrument possesses a high sensitivity and speedy response, and if the process has a relatively high capacity. On a large storage tank, for example, where it is desired to maintain the tank at a certain level or to refill it to the same level time after time, on-off control will usually perform satisfactorily.

Proportional Control

As the name implies, this form of control provides movement of the control valve proportional to the deviation of the measured variable from the desired value. It is a refinement of on-off control and smoothes out the cycling above and below the set point which would result from alternating full open and tight shut valve action. Proportional control becomes of definite value when the process capacity is small and when cycling of the controlled variable cannot be tolerated.

Proportional-Plus-Reset Control

Where the possibility of load changes exist and where precise control is essential, automatic reset is combined with proportional control. Control of liquid level in a rotary vacuum filter preparing lime mud for the kiln is an example of an application where this form of control is justified. Here level is critical since it influences the degree of wetness of mud leaving the filter. Load changes likely to be encountered are: variations in the specific gravity of mud flowing to the filter, fluctuations in filter cylinder efficiency caused by partial clogging of the wire mesh, and possible changes in the amount of vacuum delivered by the pump. The combination of proportional action plus automatic reset permits the controller to compensate for process fluctuations and to hold the controlled variable within extremely narrow limits.

Rate Action

This is a control refinement which can be added to pneumatic controllers of the proportional type. It

is designed specifically for processes where the lag is excessive. Briefly, it is a method of permitting the controller to overcorrect temporarily when the measured variable deviates from the desired value. The rate action unit in effect gives the lagging variable a sudden "shot in the arm" to hurry it up toward the set point. This unit was developed primarily for processes having excessive lags, and finds very little use in the pulp and paper industry.

Time-Pattern Transmitter

Although not actually a control form, this device enters the picture when a time-variable relationship must be established. In a process where the level of some liquid must be brought very carefully up to some specific value during a definite timed period, held at this level for a certain time, and then increased or decreased at a fixed rate, the time-pattern transmitter can do the job. It is a device which automatically positions the set point index of a control instrument in accordance with the configuration of a clock-motor driven cam which has been cut to the shape of the required time-variable (in this case, liquid level) curve.

This device does not find much use in the mill in conjunction with liquid-level controllers, but is widely used with temperature and pressure controllers in maintaining the correct time-temperature and time-pressure relationships during the cooking period in both sulphite and sulphate digesters.

SELECTION OF INSTRUMENTS FOR OTHER VARIABLES

The purpose of this paper is to show some of the factors that should be considered when selecting indicating, recording, or control instruments for mill processes. Liquid level was chosen as an example because every papermaker is familiar with the large number of mill processes where measurement or control of this variable must be considered.

Received March 1, 1949. Presented at the Annual Meeting of the Technical Association of the Pulp & Paper Industry, Hotel Commodore, New York, N. Y., Feb. 21–24, 1949.

Paper Properties Influencing Quality of Laminates

J. C. PITZER

Several properties which can be varied in the manufacture of a saturating paper show a marked influence on the quality of the finished laminate. Among these properties are: furnish, slime or shives, apparent density, formation, and strength. Illustrations are given which indicate that such laminate qualities as heat resistance, blistering tendencies, and punching are affected by one or more of the paper properties indicated. Test data are given to indicate that qualities which can be measured quantitatively such as water absorption, bonding strength, and flexural strength are influenced by paper properties especially under certain conditioning procedures.

More than 50% of the restaurant tables and dinette tables being marketed today are surfaced with a laminated plastic sheet. A high percentage of new bus, railway car interiors, hotel furniture and residential sink drain boards are also finished entirely or in part with decorative laminates. In addition to these decorative applications many of the electrical insulating applications in the electronic, x-ray, and power distribution field depend on the good qualities of thermosetting plastic laminates. All of the decorative laminates as well as many of the industrial laminates are made with a paper filler. It is important that products having such a vital part in our everyday lives be made from a paper having certain well-defined characteristics in order to produce laminates having satisfactory qualities when in service.

Several types of paper are used in the manufacture of thermosetting laminated plastics. Paper is used to contribute certain characteristics to the finished product as well as to serve as a carrier for the resin which is incorporated into the plastic. Kraft papers are used as a filler for decorative laminated plastics and in certain types of industrial laminated plastics where strength is of major importance. Sulphite papers of high alpha-cellulose content or straight alpha papers are used for backgrounds for certain decorative prints which are used as surface design sheets and for industrial materials where electrical characteristics are of major importance. Alpha papers are also used for overlay sheets on printed design sheets. Rag papers when used for the same application impart less color than do alpha papers, and rayon papers give a maximum of transparency due to the index of refraction being more nearly that of the resin. Cotton content papers may be used for certain applications in laminates where the finished material is to be molded, fabricated by intricate machining, or the finished piece is to be produced by shearing or punching. The choice of the paper to be used depends, to a great extent, on the qualities which are to be made to predominate in the finished laminate. One sheet of decorative laminate may contain as many as four kinds of paper.

The laminator has several means for influencing the quality of the finished laminated sheet. These may be altered by the types of synthetic resin used such as those made from cresols, phenols, melamines, or polyesters. The molecular size and the amount of the resin in a finished material has a marked influence on the finished properties as well as the degree to which the resin is cured in the drying operation prior to laminating under heat and/or pressure. For the purpose of this paper comparisons will be made in which the resin content and type of resin are held constant. The conditions which bring about different results will be considered in terms of different conditions of paper which go into the laminated sheet.

Many of the qualities which are incorporated into laminates by use of paper cannot be expressed as test values. These may or may not be related to certain

J. C. Pitzer, Member TAPPI; Engineering Dept., The Formica Co., Cincinnati, Ohio.

properties of the paper which can be evaluated in terms of numerical values. The final result is more observable by inspection of the ultimate product. Such paper defects as shives and slime spots may occur in papers at very infrequent intervals and yet such conditions may lead to the loss of laminated sheets in exactly the same numerical quantity as the frequency of such slime spots occur. For example, slime spots which frequently occur in kraft paper, if not detected as the paper goes through the coating and sheeting processes and then becomes a part of the laminated sheet may cause a blister or a discoloration on the surface if the spot is next to the surface sheet. Such a blister, which has been partially cut away, is shown in Fig. 1. This blistering condition is likely caused by the fact that the slime spot does not accept resin and the slime in itself acts as a thermoplastic material in the pressing process. The material is subjected in the pressing process to temperatures higher than those which the slime will withstand. Also due to the smooth surface of the slime spot there is no adhesion from the adjacent laminations and consequently the material separates at that point. When the sheet is removed from the press, the finished material will also blister due to the accumulation of gases and the lack of bond within the sheet at the point of the slime spot. This one spot can be the cause of the loss of the entire sheet since decorative sheets are usually produced for use on large areas. Similar blisters will occur in the finished sheet if the formation of a paper is uneven to the extent that unsaturated fiber bundles remain during the impregnating process. While the resin may flow into the unimpregnated fibers to some extent during the curing and pressing process, if the fiber bundles are so hard that they will not readily accept the resin, a blister will result in the finished sheet at the point where the unsaturated fiber bundles occur. Paper that is to be used for decorative overlays which contains shives, dirt specks, and foreign particles of any kind will be responsible for unsatisfactory quality material. Certain qualities of industrial laminated material such as shearing and punching are also influenced by paper fibers which are too hard or brittle. For this type of product the

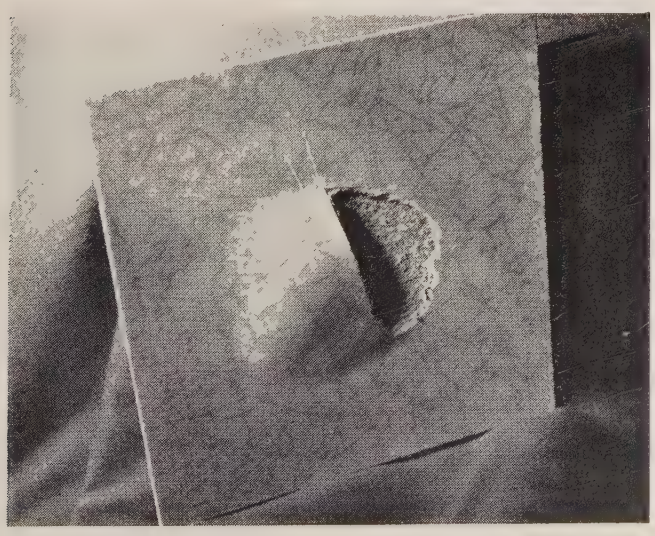


Fig. 1

Fig. 2

paper fibers must impart toughness and be able to flex with the resin. Illustrations are given in Fig. 2 which shows the type of defect that occurs when the material is sheared or punched. The shear cracks can be observed on the sheet which is made from hard paper whereas the sheet which is made from a soft paper containing cotton linters gives a satisfactory shearing condition for sheets of the same thickness. Punched pieces that are made from a hard paper give a bad undercut edge as compared to a similar punching made from a soft paper.

Some of the effects of paper on laminates can be measured quantitatively. These qualities which can be expressed in numerical terms generally can be related to certain properties of the paper which can be measured in a numerical manner. One of the properties of a laminate most affected by paper is the flexural strength. This property is especially affected if the test is made after the finished material has been subjected to adverse conditioning prior to the test. A conditioning procedure to which the material is commonly subjected is by immersing the specimen to be tested in water for 48 hours at 50°C. prior to making the test. Tensile or bursting strength tests on the paper to be made into a laminate can be very closely correlated with the flexural strength of the finished laminate. Table I indicates the comparative properties of two papers which were used in making up two sheets of laminates with the same resin and resin content. The flexural strength of the laminate made from each paper is also given.

Table I. Comparative Properties of Kraft Paper Related to Flexural Strength of Laminates

Paper	*Tensile strength* Mach.	Cross	*Air resistance, 100 cc., sec.*	*Penetration 760 cp. caster oil*	*Formation*	*Finish*
			90-Pound 9-Point Kraft			
A	48	24	40	10–85	Wild	High
B	37	24	12	12–40	Uniform	Rough

Paper	*Condition A* Mach	Cross	*Condition D-48/50* Mach	Cross
		Flexural Strength		
A	22,200	16,700	6,650	5,990
B	19,500	16,100	13,280	12,530

Fig. 3

It can be observed that the apparent density of these papers are similar but the tensile strength, bursting strength, air resistance, penetration, and surface finish are quite different. While the flexural strength of the paper with high original strength is greater in the "as received" condition, it drops off considerably when tested after immersion. The more satisfactory paper gives results in which the specimen breaks in the normal manner as is illustrated on the right in Fig. 3. The unsatisfactory material gives specimens which break by shear rather than in the conventional manner. This shear condition tends to give a flexural strength value very much lower than a specimen which breaks in the conventional manner. Paper which is made from fiber that becomes brittle from heat during the drying or curing operation will also produce a lower flexural strength than will paper which retains considerable toughness. ASTM Method D-202 describes a test for predicting the deterioration of a paper when subjected to heat.

Another quality of laminates which is materially influenced by the properties of the paper is the water absorption. Water absorption is extensively used as a measure of the dimensional stability and stability of electrical properties in a laminated material. Standard test specimens for water absorption are usually 1 inch by 3 inch by the thickness of the laminate under consideration and the specimen is allowed to remain in water for 24 hours. This test only gives a rate of absorption as total absorption may require several months. Kraft papers generally produce laminates which have much higher water absorption than do laminates which are made from alpha or rag papers. Table II indicates the comparative water absorption of laminates of the same thickness which are made from several different types of paper.

Table II. Water Absorption 45% Resin Laminates Various Types Paper

Type paper	*Water absorption per cent gain 1 × 3 × 1/8—24 hr.*
0.005 Hard finish kraft	5.7
0.009 Kraft	4.1
0.006 Sulphite	2.3
0.004 Alpha	1.7
0.004 Rag	1.3
0.010 Cotton linters	1.8

This quality of a laminate can be materially affected by the use of a high-resin surface sheet which is often made from a different paper from the body of the sheet. For the purpose of this comparison the same material was used throughout the thickness of the sheet. Not only is there a wide variation in water absorption between different paper base materials as measured by weight gain, but dimensional change (the swelling in thickness or increase in linear dimensions) can be greatly influenced by the type paper fiber used in making a laminate.

Bonding strength or ply adhesion of a laminate is a guide to the machining or drilling qualities. A paper base laminate having a high-bonding strength can be drilled parallel to the lamination much better than a low-bonding strength material without the danger of cracking between the holes. Also milling operations can be performed parallel to the laminations without danger of pieces cracking off. Tubing can be machined into spools with thinner flanges when the material has high-bonding strength. This quality is greatly influenced by the surface finish of the paper from which the laminate is made. Papers having a great amount of "tooth" or exposed surface fibers will give a much higher bonding strength than will smooth hard-finished papers. This is likely a possible explanation why rag or cotton linters bearing papers have a higher bonding strength and are consequently, better machining than are sulphite or alpha papers.

The compressive strength of a laminate especially in the edgewise direction can be closely related to the same properties of paper which influence the bonding strength. The Izod impact strength of a laminate is influenced by the combined toughness of the paper and the resin used for impregnation. Papers which embrittle also tend to give lower Izod impact strength.

Paper will continue to be used as the base for the major part of laminated plastic products produced by both high-pressure and low-pressure technique in this country. It is likely that the methods for evaluating the suitability of a paper for use in a laminate may be radically different from those commercially used for evaluating papers for many other applications. For example, absorption tests in which water is used as an absorbing medium do not have any definite relationship to the ability of a paper to absorb synthetic resins. The most suitable medium is the resin with which the paper is to be saturated but this is not always feasible. Considerable thought is being given to the development of suitable absorbency mediums which will be useful as a control test in the paper mill as well as in the laminator's plant. The rapidly increasing volume of decorative laminates being produced also calls for improvements in paper with regard to such properties as cleanliness and formation. At the present time there is no method in common use for the satisfactory numerical evaluation of formation, but it is hoped that such a test method may be forthcoming in the very near future. Only by using the combined technical knowledge of the paper producer, the paper technician, and the laminated plastic engineer can papers be developed which will contribute optimum qualities in laminated plastic materials.

Received May 4, 1949. Presented at the Annual Meeting of the Technical Association of the Pulp & Paper Industry, Hotel Commodore, New York, N. Y., Feb 21–24, 1949.

ASSOCIATION NEWS AND EVENTS

TAPPI Fall Meeting

WEDNESDAY, SEPTEMBER 14
(MULTNOMAH HOTEL, PORTLAND, ORE.)

8:00 a.m. *Men's Breakfast (Grand Ball Room)*
Sponsored by International Brotherhood of Migratory Peddlers W. R. 1

9:30 a.m. *General Session (Assembly Room)*

W. F. HOLZER, *presiding*

1. Welcoming remarks
2. The President's Message—A. E. BACHMANN
3. The Secretary's Message—R. G. MACDONALD
4. The Shibley Award
   The Meaning of the Shibley Award—Wm. R. Barber
   Presentation of Awards—A. E. Bachmann
   The Shibley Award Paper, "The Separation of Dirt from Unbleached Pulp by Centrifugal Type Classifiers," by Vance Reynolds, Puget Sound Pulp and Timber Company, Bellingham, Wash.
5. "The Status of the Pacific Coast Pulp and Paper Industry," by Lawson Turcotte, Vice-President, Puget Sound Pulp and Timber Company, Bellingham, Wash.
6. "Japanese TAPPI and Its Influence in the Japanese Pulp and Paper Industry," by H. R. Murdock, Robert & Company Associates, Atlanta, Ga. Formerly Chief of Pulp and Paper Branch, Natural Resources Section, G.H.Q., Tokyo, Japan

12:15 p.m. *Luncheon (Rose Bowl)*

R. J. LEROUX, *presiding*

Speaker, Harold S. Foley, President, Powell River Company, Ltd., Chairman, Canadian Paper and Pulp Association

2:00 p.m. *Technical Sessions*
Engineering (Junior Ball Room)

G. H. PRINGLE, *presiding*

1. "Corrosion and Corrosion Testing in the Pulp and Paper Industry," by R. A. Huseby and M. A. Sheil, A. O. Smith Corporation, Milwaukee, Wis.
2. "Hydraulic Barking, A Summary," by L. E. Hill, Pulp Division, Weyerhaeuser Timber Company, Everett, Wash.
3. "Paper Mill Design and Construction," by J. H. McCarthy, St. Regis Paper Company, Tacoma, Wash.

Fundamental Research (Marine Room)

J. L. MCCARTHY, *presiding*

1. Opening Remarks by the Chairman of the Fundamental Research Committee. H. F. Lewis, The Institute of Paper Chemistry, Appleton, Wis.
2. "Report on Lignin Studies under the Pulp Mills Research Project at the University of Washington," by D. M. Ritter, and J. L. McCarthy, University of Washington, Seattle, Wash.
3. "A Commercial Method of Isolating Conidendrin from Waste Sulphite Liquor," by Homer B. Lackey, W. W. Moyer and W. M. Hearon, Central Research and Technical Department, Crown Zellerbach Corporation, Camas, Wash.
4. "Surface Area of Fibrous Materials Using an Air Permeability Method," by J. C. Brown, Jr., The Institute of Paper Chemistry, Appleton, Wis.
5. "Recent Developments Relating to Fine Structure of Cellulose Fiber," by Otto Goldschmid, Rayonier, Inc., Shelton, Wash.
6. "Microscopical Determination of the Arrangement of the Cellulose Crystallites in Bass Wood," by G. J. Ritter, Forest Products Laboratory Madison, Wis.

Sulphite Pulping (Assembly Room)

G. H. MCGREGOR, *presiding*

1. "Digester Linings for Soluble Base Sulfite Pulps," by E. F. Tucker, Stebbins Engineering and Manufacturing Company, Watertown, N. Y.
2. "Progress Report on Magnesia Base Pulping," by S. E. Hazelquist, Pulp Division, Weyerhaeuser Timber Company, Longview, Wash.
3. "Certain Factors That Influence Delignification in Acid Sulphite Pulping," by G. A. Richter, Eastman Kodak Company, Rochester, N. Y.

9:00 p.m. *Informal Dancing (Grand Ball Room)*

THURSDAY, SEPTEMBER 15 (MULTNOMAH HOTEL)

9:30 a.m. *Technical Sessions*
Papermaking (Assembly Room)

A. E. BACHMANN, *presiding*

1. "Beater Additives in Papermaking," by D. T. Jackson, Hammermill Paper Company, Erie, Pa.
2. "Effect of Phenolic Resins on Physical Properties of Kraft Paper," by P. K. Baird, R. J. Seidl, and D. J. Fahey, U. S. Forest Products Laboratory, Madison, Wis.
3. "Consumers' Ideas on Paper Quality," by F. H. Abbott, III., Sunset-McKee Company, San Francisco, Calif.
4. "Developments for the Fourdrinier Paper Machine," by Lloyd Mornbostel, Beloit Iron Works, Beloit, Wis.

Alkaline Pulping (Blue Room)

H. C. WALL, *presiding*

1. "Sulphate Pulping of Logging and Sawmill Wastes of Old Growth Douglas Fir and of Certain Associated Species," by J. S. Martin, U. S. Forest Products Laboratory, Madison, Wis.
2. "Centrifugal Clarification of Kraft White Liquor," by A. E. Reed and W. F. Gillespie
3. "The Relation of Kraft Pulp Quality to Wood Properties of Douglas Fir," by R. N. Hammond and P. S. Billington, Research Department, Pulp Division, Weyerhaeuser Timber Company, Longview, Wash.

Symposium: Comparative Studies of Douglas Fir, Western Red Cedar, Western Hemlock, Loblolly Pine, and Black Spruce as Pulpwoods (Marine Room)

H. F. LEWIS, *presiding*

1. "Sources of West Coast Pulpwoods," by J. M. McEwen, Research Department, Pulp Division, Weyerhaeuser Timber Company, Longview, Wash.
2. "The Chemical Constituents of the Woods," by H. F. Lewis, The Institute of Paper Chemistry, Appleton, Wis.
3. "The Pulping of the Woods," by K. G. Booth and W. F. Holzer, Central Research and Technical Department, Crown Zellerbach Corporation, Camas, Wash.
4. "Specific Morphological, Chemical, and Physical Properties of the Kraft Pulp Fibers," by H. F. Lewis, The Institute of Paper Chemistry, Appleton, Wis.

5. "Comments on the Springwood and Summerwood Fibers of Douglas Fir," by W. F. Holzer and H. F. Lewis, Central Research and Technical Department, Crown Zellerbach Corporation, Camas, Wash., and The Institute of Paper Chemistry, Appleton, Wis., respectively.

12:15 p.m. *Luncheon (Grand Ball Room)*

A. E. Bachmann, *presiding*

"Management's Job Is Selling," by Alexander R. Heron, Vice-President, Crown Zellerbach Corporation, San Francisco, Calif.

2:00 p.m. *General Session (Assembly Room)*

K. P. Geohegan, *presiding*

1. "The Economic and Social Status of the Pulp and Paper Industry," by E. W. Tinker, Exec. Secy., Am. Paper and Pulp Assoc., New York, N. Y.
2. "The Position of Cellulose as a Chemical Raw Material," by L. S. Sinness, Director of Research, Rayon Division, E. I. du Pont de Nemours & Co., Inc., Wilmington, Del.
3. "Trends of Research in the Cellulose and Pulp Field," by Emil Heuser, La Jolla, Calif.
4. "The Problems of Education in the Pulp and Paper Field," by John G. Strange, The Institute of Paper Chemistry, Appleton, Wis.

6:00 p.m. *Get-together Party (Assembly Room)*

7:00 p.m. *Banquet (Grand Ball Room)*
Entertainment and Dancing — to 1:00 a.m.

New Committee Chairmen

August S. Erspamer, Technical Director, P. H. Glatfelter Co., Spring Grove, Pa., has been appointed *Chairman* of the TAPPI Water Committee in the Industrial Division to succeed Lewis B. Miller (deceased). During the period of Dr. Miller's illness Miss Louise E. McGrath of the Booth Chemical Co., Elizabeth, N. J., has been *Acting Chairman.*

Hermon T. Barker, Chief Chemist, Bird & Son, Inc., E. Walpole, Mass., has succeeded W. B. Lincoln, Jr., of the Inland Container Corp., Indianapolis, Ind., as *Chairman* of the TAPPI Containers Committee in the Converting and Consuming Division.

Year Book and Directory

The 1950 TAPPI Year Book will be published this fall. Members are urged to check their listing in the 1949 Year Book and advise the Secretary of the Association if any changes in position or address should be made.

Executive Committee Meeting

The Executive Committee of the Technical Association met at the Association headquarters in New York on June 29, 1949.

A considerable part of the program was devoted to a review of the activities of the divisions and committees.

It was voted to send a questionnaire to all members to find out who can supply samples of specified fibers to be kept at the Institute of Paper Chemistry for use of fiber microscopists.

The Secretary reported that the Fundamental Research Committee is making preliminary plans to hold a meeting, possibly in Canada in June, 1950, to consider the papermaking properties of fibers. The meeting will probably be co-sponsored by the Wood Chemistry Committee of the C.P.P.A. Technical Section.

It was voted to permit a library of United States Government, states, municipalities, and educational institutions to hold affiliate membership in the Association, appointing an individual as its representative.

It was voted to appropriate funds to finance a research project at Bucknell University on some aspects of lignin chemistry. This appropriation was requested by the Fundamental Research Committee.

It was voted to appropriate funds to assist local sections to defray expenses of some meeting speakers.

The business aspects of the Association's magazine *Tappi* were reviewed. Appreciation was expressed relative to those companies who did much to encourage this important publication effort through their use of advertising space. It is hoped that conditions will permit other companies to be able to benefit through use of its advertising pages in the coming year.

Routine Control Methods

Members of the Association are familiar with the TAPPI Standards. For some time it was felt that the empirical procedures used by many pulp and paper mills to evaluate their products, especially for operation control should be made available in a form that would be generally useful but would not be considered to be sufficiently qualified to be approved, in their present state as official methods of the Association.

The local sections were requested to obtain methods of this kind from the mills in their respective areas. The effort was first made by the Pacific Section, with excellent results and then each section proceeded to make accumulations of methods used locally.

The following is a list of 157 new TAPPI Routine Control Methods. The names of the original contributors will not appear on the methods so this opportunity is taken to express the appreciation of the Association to those who helped in this fine work.

It is planned to print these methods in a manner that will distinguish them from the Standards. These will be made available to members later in the year. However, to expand this service and to build up a larger collection it is requested that members who write to the Secretary of the Association for a copy if they have not contributed already, will, at the time, enclose a description of one or more of their routine methods.

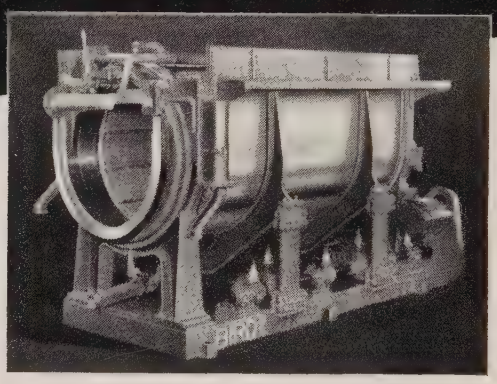
In this way the service can be made as complete as possible and it is likely that many of these methods will provide an excellent source of future TAPPI Standards. Requests for the Methods and contributions of additional methods should be sent to TAPPI, 122 East 42nd Street, New York 17, N. Y.

Index to TAPPI Routine Control Methods

RC- 1 Ash in Paper—(1 gram in muffle furnace)
2 Basis Weight of Towels—($9^5/_{16} \times 14^3/_{16}$ template)
3 Bleeding Test for Dyed Papers—(boil test)
4 Blood Resistance of Paper—(serum) (blood serum and Na_2CO_3)
5 Blood Resistance of Paper— (ink) (ink penetration)
6 Bonding Strength of Paper—(transverse tensile with wax)
7 Brightness of Paper—(reciprical method)
8 Capillarity Test of Paper—(rise of water)
9 Preparation of Hand Sheet Color Samples—(wire mold and wringer)
10 Sizing of Paper—(reverse curl) (light and heavy paper)
11 Glue in Paper—(tannic acid ppt.)
12 Grease Resistance of Paper—(turpentine)
13 Grease Resistance of Paper—(oleic acid)
14 Ink Penetration of Paper—(flotation)
15 Ink Penetration of Paper—(ply flotation)
16 Ink Penetration of Paper—($^1/_2$ hour flotation)
17 Ink Penetration of Paper—(opacimeter)
18 Resistance of Paper and Paperboard to Printing Ink —(butyl carbitol drop) (K & N ink)
19 Resistance of Paper and Paperboard to Printing Ink (K & N ink)
20 Moisture in Paper—(rapid oven)

(continued on page 42 A)

NOW



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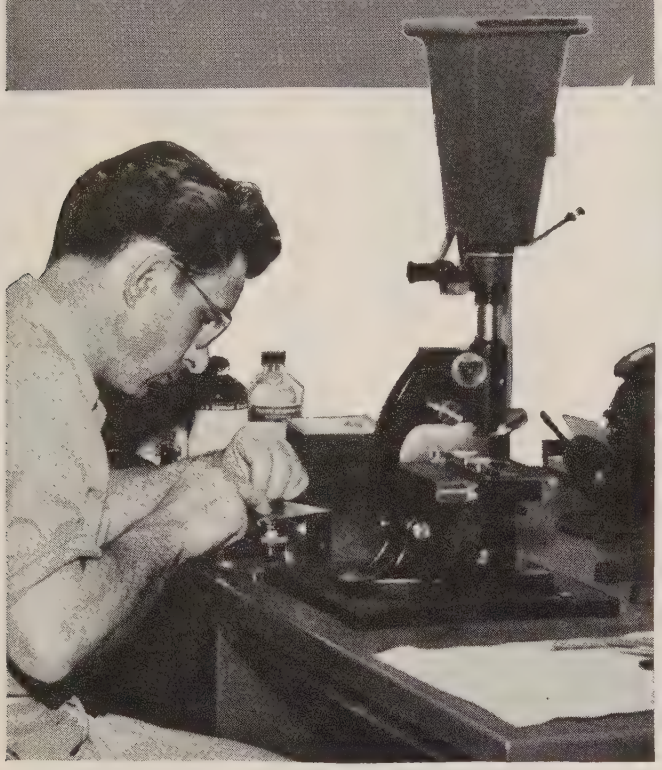
PROGRESS IN FELTS



OVER THE ENTIRE SPAN of modern paper manufacture, paper machine felts have been made in the same general way—same general way, that is, until Orr chemically-treated felts appeared.

Development of ORR-CHEM (treated) felts is now gradually revolutionizing the art of felt manufacture—not the actual weaving of the felts, but the further processing of them after weaving to insure better service on the paper machine than would otherwise be possible.

Now, a fully-equipped laboratory has been installed in which to study and test felts—for stretch, porosity, fatigue resistance, etc.

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ORR-CHEM

21 Moisture in Paper—(Emerson dryer)
22 Moisture in Paper—(Moistrite register)
23 Moisture in Paper—(Sword hygrometer)
24 Moisture in Paper—(Hart meter)
25 Moisture in Paper—(Dietert moisture teller)
26 Oil Absorbency of Paper—(heavy mineral oil)
27 Oil Absorbency of Paper—(light mineral oil)
28 Oil Absorbency of Paper—(castor oil)
29 pH of Paper—(cold extract)
30 pH of Paper—(spot test) (with indicator)
31 Paraffin Wax Absorbency of Paper—(immerse; scrape and weigh)
32 Schmidt's Reagent—(two solutions for prolonged keeping)
33 Prussian Blue in Paper—(alkali thiocyanate test)
34 Slip Test for Wax Paper for Cups—(inclined plane, paper on paper)
35 Slip Test for Candy Cup Paper—(force to pull steel block on surface)
36 Smoothness of Paper—(apparatus for lateral porosity)
37 Softness of Tissue Paper—(weight of shot to crumple paper to volume)
38 Wet Tensile Strength of Paper—(wetting agent)
39 Wet Tensile Strength of Paper—(immersed in water)
40 Wet Tensile Strength of Paper—(methanol)
41 Wet Tensile Strength of Paper for Coating—(after immersion)
42 Titanium in Paper—(qualitative and quantitative peroxide)
43 Oil Spots in Paper—(ultraviolet test)
44 Water Penetration of Paper—(Dry indicator) (apparatus)
45 Water Absorbency of Paper Towels and Tissue—(modification of T 432 m)
46 Water Absorbency of Kraft Paper Yarn—(low-surface tension solution)
47 Surface Receptivity of Paper to Water—(drops water rolled down surface)
48 Wet Bursting Strength of Paper—(using mercury and special apparatus)
49 Surface Absorbency of Paper to Liquids—(measure length of streak from drop)
50 Fading Resistance of Paper and Paperboard—(Atlas Fadometer 30 hrs.)
51 Fire Resistance of Wallboard—(composite strip burned in tube)
52 Grease Absorbency of Paperboard—(dip in hydrogenated oil)
53 Iron Particles in Paper or Paperboard—(immerse in ferrocyanide)
54 Moisture in Paperboard—(120°F. oven)
55 Moisture in Paperboard—(hotplate)
56 Moisture in Paperboard—(275°F. oven)
57 Moisture in Paperboard—(Williams oven)
58 Moisture in Paperboard—(template and steam oven)
59 Nailing Quality of Paperboard—(resistance to special nail)
60 Oleic Acid Penetration of Paperboard—(float on acid)
61 Wax Pick Test of Paperboard—(modification to 459 m)
62 Printing Varnish Absorbency of Paperboard—(time for varnish to go after pressure)
63 Rigidity of Paperboard—(penetrometer to load small beam)
64 Rigidity and Brittleness of Paperboard—(beam test with liquid loading)
65 Sampling and Testing Schedule in a Paperboard Mill
66 Scoring Bend of Boxboard—(special creasing rules)
67 Sizing Tests for Boxboard—(general)
68 Sizing Tests for Boxboard—(bucket test)
69 Sizing Tests for Boxboard—(warm water penetration)
70 Sizing Tests for Boxboard—(drop dyed water)—for unsized board
71 Sizing Tests for Boxboard—(Immersion No.)—6 × 6 sample 10 min. 73°F.
72 Sizing Tests for Boxboard—(flotation)
73 Sizing Tests for Boxboard—(loss of bursting)
74 Surface Sizing (Feathering Test for Index Bristol—(Malachite green solution)
75 Snap Test for Bristol Board—(springiness by striking ball in tube)
76 Stiffness of Thin Paperboard—(Elmendorf tearing tester used to load specimen)
77 Ply Thickness of Liner Board—(insert tissue between cylinders of machine)
78 Varnish Test for Bristol Board—(appearance after varnish spread 1 min.)

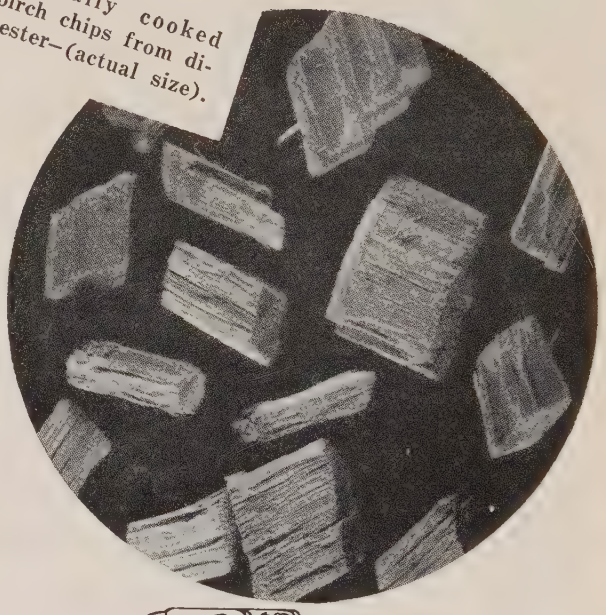
(continued on page 44 A)

from birch and aspen *now* come semi-chemical pulps

1

YES! GO WEST!
1949 Fall Meeting TAPPI
Portland, Ore.

Partially cooked birch chips from digester—(actual size).



ABUNDANT and fast growing, these hardwoods are capable of vast increases over standard yields after sodium sulphite treatment followed by SPROUT-WALDRON refining.

Readily bleached and with high initial strengths, such pulps may be substituted for bisulphite in book and comparable grades.

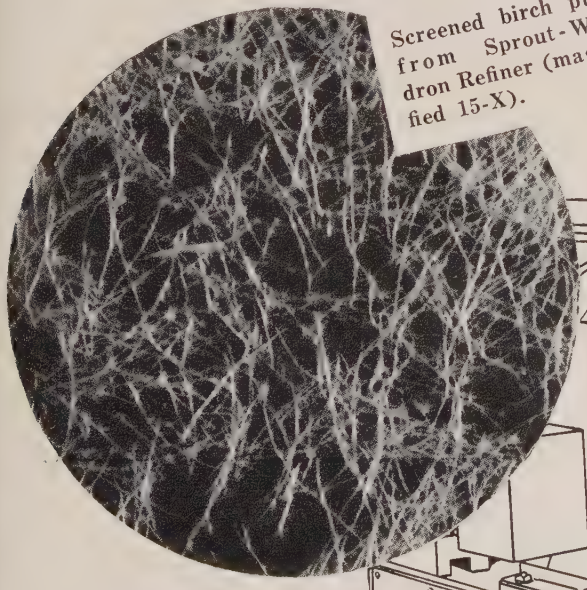
Low power and high increments of clean, uncut fibers, offer inducement to serious consideration.

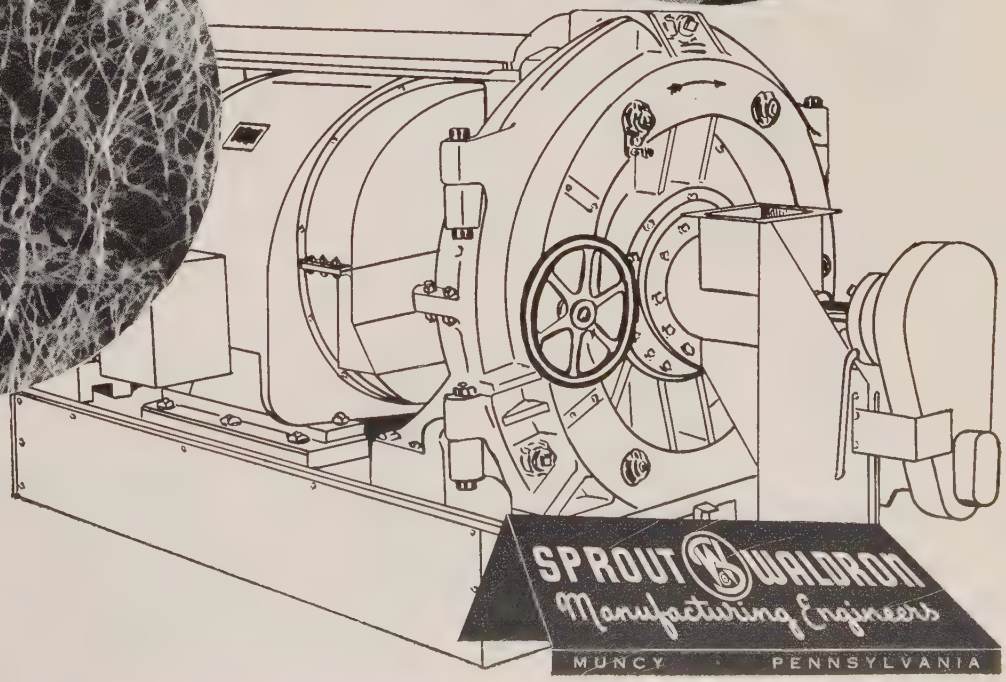
SPROUT-WALDRON offers you its technical knowledge and experience in consultation.

Sprout, Waldron & Co., 38 Waldron St., Muncy, Pa.

2

Screened birch pulp from Sprout-Waldron Refiner (magnified 15-X).





44-C

pulp whitening

PQ SILICATES AID PULP WHITENING

More and better paper always starts with whiter, cleaner pulp. And PQ Silicate assistance starts there too. Leading mills that bleach groundwood pulp rely on PQ Silicate to stabilize the peroxide solutions. PQ's recognized uniform quality secures top benefits from the peroxide. In hypochlorite bleaching, also, the use of PQ Silicate increases brightness. Successful de-inking formulae regularly specify PQ Silicate for these important advantages:

wetting properties
deflocculating of solid dirt
suspending of removed dirt

Know how PQ Silicates can improve your products or your profits. Ask for Bulletin No. 17-1 which describes the properties and uses of PQ Silicates.

PHILADELPHIA QUARTZ CO.

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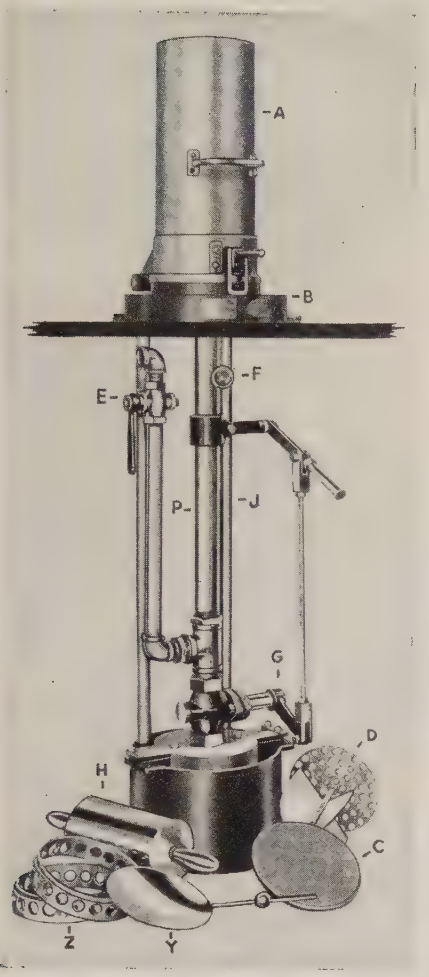
JEFFERSONVILLE, IND.
KANSAS CITY, KANS.
RAHWAY, N. J.
ST. LOUIS, MO.
UTICA, ILL.

79 Water Absorbency of Bristol Board—(sealed edges)
80 Surface Oil Absorbency of Paperboard—(roller)
81 Surface Oil Absorbency of Paperboard—(roll and inclined plane)
82 Waxing Test for Paperboard—(molten wax then cold water)
83 Weight Variations across Web—(selection of weight samples)
84 Sampling Wood Chips from Conveyor—(composite grab samples)
85 Wood Chips Length Analysis—(measurement)
86 Wood Chip Length Analysis—(two screen)
87 Wood Chip Length Analysis—(four screen)
88 Moisture in Wood Chips—(steam oven)
89 Moisture in Wood Chips—(moisture teller)
90 Density of Wood Chips—(sheet mold cylinder)
91 Density of Wood Chips—(two-liter cylinder)
92 Dirt Count of Wood Chips (knots, bark and rot)
93 Usable Fiber in Tailings—(laboratory screened)
94 Specific Gravity of Wood Disks—(displacement in special cylinder)
95 Solids in White Water—(filter 835 ml.)
96 Ten Per cent Alkali Solubility of Pulp—(7.14% NaOH)
97 Beater Tests of Pulp—(made at 5, 15, and 45 minutes)
98 Residual Bleach Demand of Pulp—(time to discharge $KmnO_4$ color)
99 Pulp Pads for Brightness—(with wringer)—2 gram pad 15 cm. dia.
100 Pulp Pads for Brightness—(with press)—2 gram pad 9 cm. dia.
101 Calcium Chloride in Bleached Pulp—(titrated with $AgNO_3$)
102 Excess Chlorine During Pulp Bleaching—(sodium metabisulphite)
103 Cleanliness Factor of Pulp—(visually compared with standards)
104 Consistency of Pulp—(centrifuge)
105 Consistency of Pulp—(lever press) (large sample)
106 Consistency of Pulp—(groundwood) (aluminum rod)
107 Dirt Count of Pulp—(handsheet with transmitted light)
108 Freeness of Pulp—(drainage cylinder)
109 Freeness of Pulp—(sample weighing)
110 Freeness of Pulp—(Williams)
111 Calibration of Canadian Standard Freeness Tester Screens
112 Moisture in Pulp—(web)
113 Moisture in Pulp—(lap)
114 pH of Stock—(Hellige and Taylor apparatus)
115 pH of Dry Sulphite Pulp—(cold extraction)
116 Permanganate No. of Pulp—(modified T 214 m)
117 Laboratory Refining of Pulp—(Mead Corp. refiner)
118 Laboratory Refining of Pulp—(Morden)
119 Shrinkage Test of Pulp Sheets—(shrinkage during drying)
120 Shives in Groundwood Pulp—(differentiating stains)
121 Cuprammomium Viscosity of Pulp—(modification of T 206 m)
122 Cupriethylenediamine Viscosity of Pulp—(modification of T 230 m)
123 Strength of Alum Solution—(titrate with NaOH)
124 Testing of Bentonite—(sampling, moisture, and oil absorbency)
125 Chlorine in Bleach—(sulphuric, hydrochloric, and Acetic acid methods)
126 Analysis of Borax—(moisture, Na_2O, B_2O_3)
127 Brightness of Powdered Materials—(pellet—prepared for Photovolt meter)
128 Testing of Clay—(moisture, brightness, grit, settling rate)
129 Density of Clay Slip—($^1/_2$ liter flask)
130 Viscosity of Clay Slip—(dough mixer and Brookfield viscometer)
131 Density of Settling Rate of Filler Slurry—(1 liter flask and 1 liter graduate)
131 Microscopical Identification of Fillers—(kaolin, talc, titanium, etc.)
133 Dilution of Lime Slurry—(titrate with HC1)
134 Lime in Lime Slurry—(titrate with HC1)
135 Strength of Milk of Lime for Sulphite Acid—(titrate with HC1)
136 Analysis of Kraft Lime Sludge—(moisture, Na_2O $Ca(OH)_2$ $CaCO_3$ Na_2S Na_2SO_4
137 Ph of Coating Mixtures—(colorimetric)
138 Sludge of Kraft Cooking Liquor—(sedimentation)
139 Active Soda in Kraft Black Liquor—(methyl orange as spot indicator)

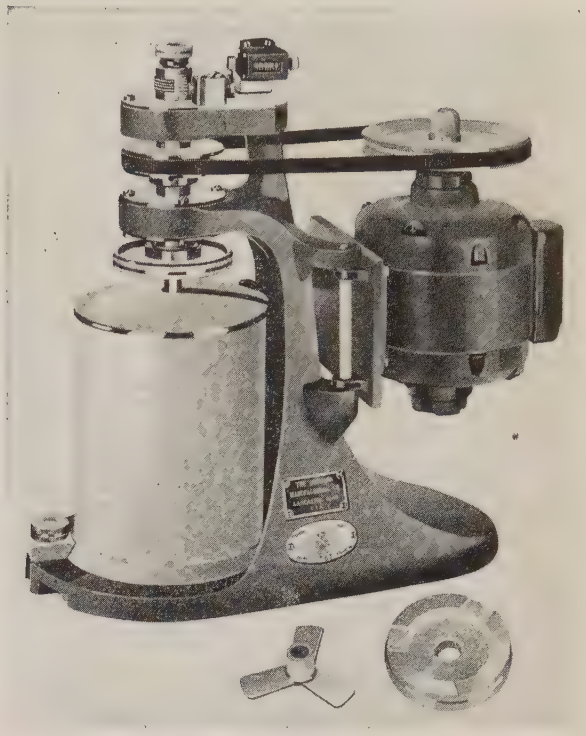
(continued on page 46 A)

*TAPPI STANDARD

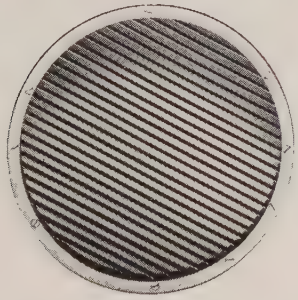
PULP TESTING — SHEET MAKING APPARATUS



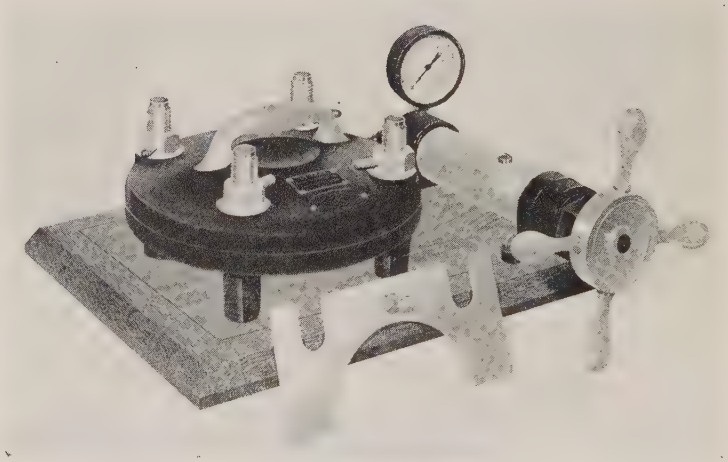
*SHEET MACHINE—DRYER RINGS—DISCS



*DISINTEGRATOR



FIBRE LENGTH CLASSIFICATION GRID
TECHNICAL ASSOCIATION PAPERS, SERIES 29-S



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NEW CATALOGUE AND PRICE GLADLY FURNISHED ON REQUEST

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MFGRS.: HERMANN IMPROVED CLAFLIN CONTINUOUS BEATER & REFINER

LANCASTER, OHIO

DICALITE
PAPER-AIDS
improve formation and give better liner coverage with less fiber

"We used the regular furnish and then without making any other changes we put in 4% Dicalite BP-2 in the under liner and the liner and 3% Dicalite BP-3 in the filler and back.

"The results became apparent immediately, showing a much better formation, better brightness, so that Mr.—— commenced to reduce the amount of bleached sulphite in the liners, and we cut back on the bleached sulphite several times so that the final furnish in the beater was 10% lower in bleached sulphite and this was the lowest amount of this material that they had ever used and still obtain a better sheet, with better coverage and brightness than with their standard furnish."

(From report of a Dicalite Engineer)

There are other advantages of using Dicalite that may be more important in your particular mill. A Dicalite Engineer will be glad to give you complete information.

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DICALITE
PAPER-AIDS FOR BETTER PAPER PRODUCTS

140 Sodium Sulphate in White and Green Kraft Liquors—(Photometer method)
141 Analysis of Green Kraft Liquor—(sulphates, Na_2S—% reduction)
142 Starch Viscosity with Dudley Pipet—(special assembly)
143 Analysis of Sulphite Cooking Acid—(iodate method)
144 Combined SO_2 in Cooking Liquor (Sander's method)
145 Sulphates in Sulphate Cooking Liquor—(gravimetric)
146 Sulphates in Sulphate Cooking Liquor—(photometer)
147 Moisture and Alkalinity of Trisodium Phosphate—
148 Turbidity of Water—(limited number of standards)
149 Coagulation Test for Raw Water—(multiple stirrers and jars)
150 Organic Matter in Mill Water—(chlorine consumption)
151 Plankton Count of Water—(microscopical investigation)
152 Primary Air to Kraft Furnaces—(velometer)
153 Standardizing Foil for Checking Mullen Testers—(weight factor method)
154 Randomizing Foil for Checking Mullen Testers
155 So_2 Content of Gas—(bubbling through iodine solution)
156 Sulphur Loss from Acid Towers—(automatic sampler for SO_2
157 Groundwood Testing—(tearing strength and freeness)

Fourth Engineering Conference

TENTATIVE PROGRAM

Monday, October 31

8:30 a.m. Registration, Statler Hotel, Boston, Mass.

9:15 a.m. Opening Addresses

by A. E. Bachmann, *President* TAPPI and G. H. Pringle, *General Chairman,* TAPPI Engineering Division

9:30 a.m. Mill Design and Economic Aspects Session

A. H. Johnson, Consulting Engineer, New York, N. Y., *Chairman*

"Pulp and Paper Mill Building Design," by M. C. Celli, Rust Engineering Co., Pittsburgh, Pa.

"Paper Machine Drives." A panel discussion under the direction of Roland A. Packard, Holyoke Machine Co., Holyoke, Mass.

11:15 a.m. Engineering Data Sheets Session

Discussion led by Henry Perry, Consultant, New York, N. Y., *Chairman* TAPPI Data Sheets Committee

12:30 p.m. Luncheon (Where you will)

2:00 p.m. Engineering Research and Machine Design Session

P. H. Goldsmith, Pusey & Jones Corp., Wilmington, Del., *Chairman*

"Suggested Standardization of Spherical Bearings on the Wet End and Drier Sections of Paper Machines," by George H. Spencer, The Torrington Co., Torrington, Conn.

Materials Handling Session

George R. Wadleigh, Consulting Engineer, New York, N. Y., *Chairman*

"Conveyors in Pulp and Paper Mills," by S. L. Foster, Kalamazoo Vegetable Parchment Co., Kalamazoo, Mich.

Tuesday, November 1

9:00 a.m. Steam and Power Session

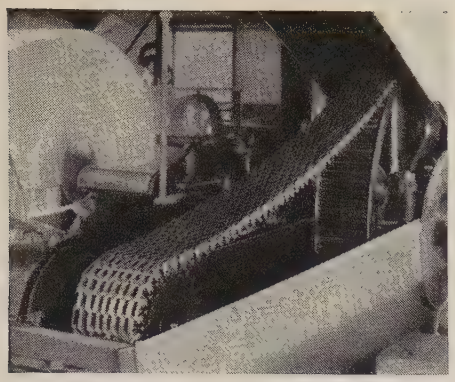
Charles J. Sibler, West Virginia Pulp & Paper Co., New York, N. Y., *Chairman*

"Developing Data for Use in Selecting Pressure and Temperature of Initial Steam Generating Plants in Paper Mills," by W. C. Bloomquist, General Electric Co., Schenectady, N. Y., and Marvin H. Dixon, St. Regis Paper Co., Deferiet, N. Y.

Papers to be announced

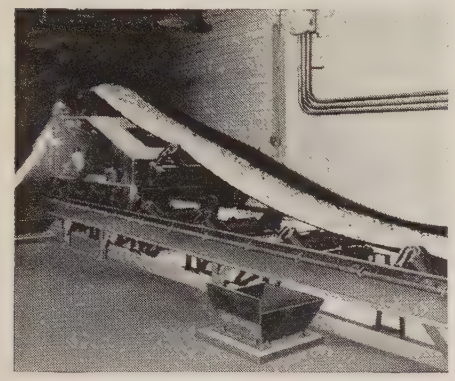
10:45 a.m. Mill Maintenance and Materials Session

(*continued on page 48 A*)



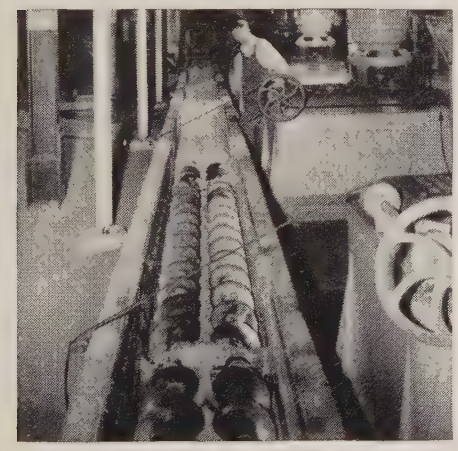
SILENT CHAIN DRIVES

The ideal drive for beaters, pumps, calendars, etc.—wherever long life and efficiency are desired.



BELT CONVEYORS

Assure efficient, high capacity handling of chips, logs, lime, sulphur, wet pulp, etc.



SCREW CONVEYOR

Commonly used in handling wet pulp, sulphur, salt, coke, etc.

CHAIN CONVEYORS

There is a type and size of chain for every conveying service . . handling logs, bark, etc.

LINK-BELT PULP AND PAPER CONVEYORS AND DRIVES

Link-Belt Standard Units plus specialized "know-how" for integrating them into operations for high efficiency, high production and low operating costs, are backed by more than 70 years of experience.

We welcome the opportunity to serve you. Catalogs on any product will be sent on request.

Other Link-Belt products, not illustrated, include: Log Haul-Ups . . . Slasher Table Chains . . . Chains for suspending and driving barking drums . . . Sorting Table Conveyors . . . Malleable Iron, Promal and Steel Chains and Attachments . . . Chemical and Refuse Conveyors . . . Skip Hoists . . . Conveyors of the Apron, Bulk-Flo, Interno, Sidekar-Karrier, Oscillating types, etc. . . . Vibrating Screens . . . Traveling Water Screens . . . Dryers and Coolers . . . Enclosed Gear Drives . . . Electrofluid Drives . . . Couplings . . . Clutches . . . Gears . . . Sprockets . . . V-Belt Drives . . . Pulleys . . . Grease Cups . . . Safety Collars . . . Base Plates . . . Shafting . . . Paper Roll Handling Equipment, etc.

LINK-BELT COMPANY

Chicago 9, Indianapolis 6, Philadelphia 40, Atlanta, Dallas 1, Houston 3, Minneapolis 5, San Francisco 24, Los Angeles 33, Seattle 4, Toronto 8. Offices in Principal Cities.

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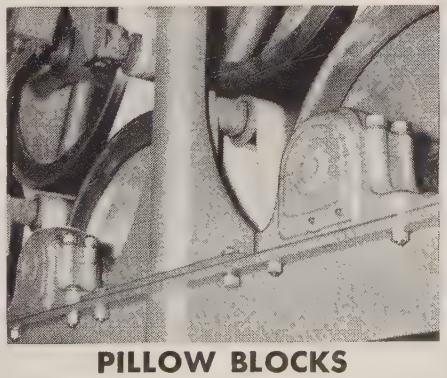


PILLOW BLOCKS

Ball, Roller and Babbitted types; flanged, cartridge, flanged cartridge, hanger & takeup blocks.

LOG STACKERS

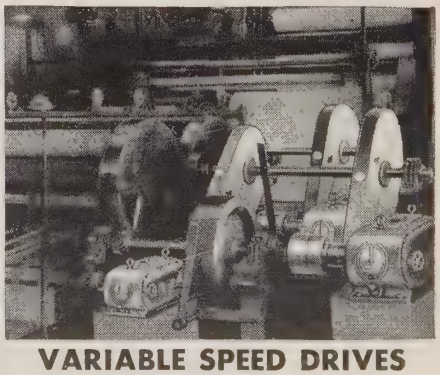
Portable and stationary types, single or double boom, for all capacities.

BELT CONVEYORS

For efficient handling of logs from pond to storage or to wood room.

CHIP FEEDERS

Rotary type for feeding wood chips to belt conveyors for delivery to digesters.



VARIABLE SPEED DRIVES

P.I.V. Variable Speed Drives accurately control speeds on cutters, press-rolls, coaters, pumps.

here's why
PENNSALT
Hydrogen Peroxide
for bleaching groundwood
SAVES YOU MONEY!

Bleached groundwood has these distinct advantages:

1 **Low cost—most of the wood entering groundwood process is recoverable.**

2 **No serious waste liquor problem.**

3 **Desirable printing properties—cushion, flexibility, ink affinity, high opacity per ream weight, ability to take coating and colors.**

The above advantages result in a saving in production costs, increased yield from available wood, and superior qualities in specific grades of paper when you bleach with Pennsalt Hydrogen Peroxide. Such paper finds popular application in items of transitory nature—such as magazine, catalog, directory, mimeograph, tablet, tissue, toweling, book and hanging papers. That's why more and more paper manufacturers are showing interest in bleached groundwood . . . bleached with Pennsalt H_2O_2!

An experienced Pennsalt representative may show you how to use Hydrogen Peroxide to advantage in your bleaching operation. Write: *Heavy Chemicals Division,* ***Pennsylvania Salt Manufacturing Company,*** *Philadelphia 7, Pa.*

PENN SALT
chemicals

Wm. McIntosh, Jr., Southern Corp., Charleston, S. C., *Chairman*

"Maintenance Costs in Fine Paper Mills," by Donald Ross-Ross, Howard Smith Paper Mills, Cornwall, Ont.

"Process Piping Other Than Black Pipe," by Fred V. Doutt, Champion Paper & Fibre Co., Canton, N. C.

12:30 p.m. Luncheon (Where you will)

2:00 p.m. Round Table Sessions

Steam and Power Committee—Round-table Discussion on "The Determination of Turbine Standards for Paper Mills"
Mill Design and Economic Aspects Committee
Engineering Research and Machine Design Committee
Hydraulics Subcommittee
Materials Handling Committee
Paper Manufacture Committee

6:00 p.m. Get-together Party

7:00 p.m. Dinner sponsored by machinery manufacturing companies in New England

Wednesday, November 2

9:00 a.m. Drying and Ventilating Session

A. E. Montgomery, J. O. Ross Engineering Corp., Chicago, Ill., *Chairman*

"Installation of White Water Heating System and Briner Economizer," by A. C. Smith, Newton Falls Paper Co., Newton Falls, N. Y.

"Pulp and Paper Mill Ventilation," Author to be announced

"Air Filtration for Pulp and Paper Mills," Author to be announced

10:45 a.m. Electrical Engineering Session

A. S. Goodrich, Hammermill Paper Co., Erie, Pa., *Chairman*

"First Report on Committee Project: Power Requirements for Paper Machines," by A. S. Goodrich

"Electrification of a Pulp and Paper Mill," by J. C. Lynch, Hammermill Paper Co., Erie, Pa.

12:30 p.m. TAPPI Engineering Division Luncheon

2:00 p.m. Round Table Sessions

Mill Maintenance and Materials Committee
Electrical Engineering Committee
Drying and Ventilating Committee
Data Sheets Committee
Paper Manufacture Committee

Thursday, November 3

9:30 a.m. Plant Visits, Leave from Hotel Statler

Walpole Trip to Bird & Son, Inc., Bird Machine Co., The Foxboro Co., and Draper Bros. Co., plants

Worcester Trip to Rice Barton Corp., Norton Co., Riley Stoker Corp., and Lodding Engineering Co., plants

Lynn Trip to the River Works, General Electric Co.

Hyde Park Trip to Sturtevant Division, Westinghouse Electric Corp. plant

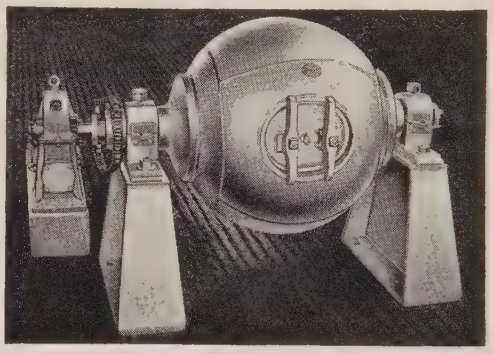
Note: The above-mentioned companies will provide transportation and group luncheons in connection with these trips

Yes—Go West!

Then—Go East!

HEAVY PLATE FABRICATORS FOR INDUSTRY

. . . that's Biggs



BIGGS built . . . laboratory type digester

SAVE ENGINEERING COSTS!

FOR THE PULP AND PAPER PROCESSING EQUIPMENT YOU NEED *TOMORROW*, CALL ON BIGGS *TODAY!*

Biggs fabricates just about any equipment you need and can save you money on your engineering —

Because . . .

1 We have standard paper mill equipment in our regular line on which we can give you prompt quotations and "quicker-than-quick" delivery — DIGESTERS, BLEACHING TANKS, RETORTS, STACKS, etc.

2 In our 62 years, Biggs has designed, built and installed a tremendous amount of specialized paper mill equipment. Check us — it's very likely one of Biggs' "proved-in-service" designs is just what you're looking for.

3 If your requirements call for a "tailored" job, Biggs can either build it from your blueprints, or handle the entire job for you — from drawing board to final installation of finished equipment.

The Biggs Boiler Works Co. Akron Ohio Est. 1857

ALL PRODUCTS WELDED TO CODE REQUIREMENTS

Carbon Steel • Special Steel
Special Alloys • Clad Metals

Call, wire or write us and a Biggs man will be out promptly and go over your job with you.

THE BIGGS BOILER WORKS COMPANY

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LOCAL SECTION ACTIVITIES

Reports of Meetings, Personnel and Events

Empire State

Banquet Head Table James E. Foote, presiding

The Empire State Section held its annual meeting on June 2–4, 1949, at the Sagamore, Bolton Landing, Lake George, N. Y.

Foster P. Doane of the Sandy Hill Iron & Brass Works was general chairman and was assisted by Jos. MacLaren, G. E. Osterheldt, Thos. Rider, C. E. Foster, Henry Fales, Mr. and Mrs. Robert Drummond, Mrs. A. B. Copping, Roger Trimbey, and K. L. Seeber.

A panel discussion on "Pollution Control in the Paper Industry" was moderated by H. A. Spencer, Knowlton Bros. Co., Watertown, N. Y., Morris M. Cohn, Consultant, Special Committee on Pollution Control, Joint Committee on Interstate Cooperation, was the principal speaker. His subject was "New York State Pollution Control Program."

V. L. Harper of the Northeast Forest Experiment Station, Philadelphia, Pa., discussed "The Wood Situation in New York State."

On Friday afternoon visits were made to the pulp and paper mills of Finch Pruyn Co., Marinette Paper Co., International Paper Co., Warrenburg Pulp and Paper Co., Imperial Paper & Color Co., and to the shops of Sandy Hill Iron & Brass Works.

On Saturday morning W. S. Yunker of the Foxboro, Mass., talked on "Getting the Dollar Value from Your Instruments." Hugh H. Lavery, Asst. Technical Superintendent of the Palmer, N. Y., Mill of the International Paper Co., described instrument control at his mill. Anthony J. Palladino, Secretary Engineer, National Council for Stream Improvement talked on "Pollution Abatement in the Pulp and Paper Industry."

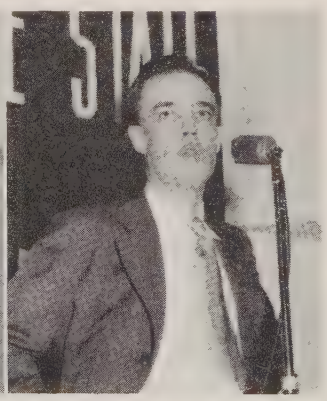
Meeting Speakers, L to R. Hugh Lavery, W. S. Yunker, A. J. Palladino, and C. E. Foster, Jr., Chairman

At the business meeting on June 3, A. E. Bachmann of the Missisquoi Corp., and President of the Association, outlined some of the objectives of his administration. In his talk he indicated his desire to emphasize an accelerated program of study of paper manufacturing techniques, cost reduction, and engineering, and urged that as many as possible plan to attend the Association fall meeting at Portland, Ore.

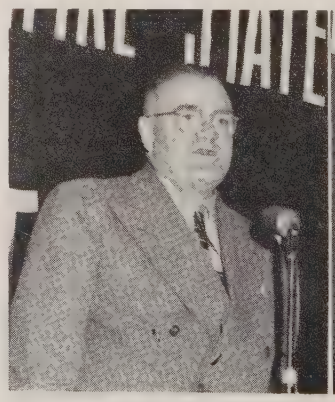
The results of the Section mail ballot were announced as follows:

Chairman: C. E. Foster, Oswego Falls Corp., Fulton, N. Y.
Secretary-Treasurer: R. N. Prince, American Cyanamid Corp., New York, N. Y.
Executive Committeemen:
J. B. Calkin, Consultant, New York, N. Y.
R. H. Wiles, International Paper Co., Glens Falls, N. Y.
J. S. Reichert, E. I. du Pont de Nemours, Inc., Niagara Falls, N. Y.
F. G. Sommerville, Armstrong Cork Co., Fulton, N. Y.
H. M. Rice, E. I. du Pont de Nemours, Inc., Watertown, N. Y.
J. F. Butterworth, Socony-Vacuum Oil Co., New York, N. Y.

James E. Foote
Chairman



C. E. Foster, Jr.
Chairman-Elect



Albert E. Bachmann
President, TAPPI

Foster P. Doane
Convention Chairman

An extensive social program was enjoyed by the men and women attending the meeting. This included golf, trap shooting, boat rides, bridge, dinners, and dancing at the Colony Club.

Excerpts from Papers

In his talk, Mr. Yunker of Foxboro Co., pointed out that the pulp and paper industry is lagging behind the petroleum refining and chemical industries in the use of instruments. He pointed out that all of the large instrument companies conduct courses of about three weeks' duration for training mill personnel in the proper use, maintenance, and operation of instruments.

Mr. Palladino of the National Council for Stream Improvement outlined the work that his organization is doing in Pennsylvania, Wisconsin, Michigan, Massachusetts, Indiana, Louisiana, and Florida, all of which recently have passed legislation preventing industry from adding new waste and providing for abatement in existing pollution.

Morris M. Cohn, Consultant, presented the background of the 1948 State Water Pollution Control Law, initiated by Harold Osterdag, Chairman of the Joint Legislative Committee on Interstate Cooperation. The law amends the public health law and code of criminal procedure and sets up a water pollution control board which will have authority to establish the classification of various waterways.

V. L. Harper of the Northeast Forest Experiment Station called attention to the deficit in soft wood growth which is used by the pulp industry and stated that less than 25% of the wood for pulp mills in the state is supplied from sources in the state. He had six suggestions to meet the shortage: using more hardwood for pulp; forest protection from fire and insects; having more mills grow timber on their own lands; adoption of different forest programs by mills; a more progressive forest policy; and proper technical information to be made available by state forestry schools.

Instrument Application at I. P. Mill

Hugh H. Lavery presented a paper outlining the application of instruments at the Palmer, N. Y., mill as follows:

For this talk I am going to try to show how instrumentation to solve specific problems is being used at the Hudson River Mill of the International Paper Company. This mill is an integrated mill making groundwood papers. It is not what might be called an instrument-controlled mill. Before instrument control became what it is today, the mill existed. However, instruments are being used to solve, or to help solve, many real problems. These problems may be broadly classed as material waste, fuel and power conservation, the human element, process or mechanical control and evaluation and maintenance. There are well over 100 recording instruments in use. I cannot guess as to the number of indicators, control valves, controllers, etc., in use.

To say that properly installed and maintained instruments cause man-power saving, ranks as a truism. Also, to say that instruments must be kept in calibration and repair is also a truism. The mill does not have one individual, an instrument repair man, responsible for the calibration and repair of instruments. Experience is a good teacher. I believe that we will have an instrument repair man in the near future.

Do not expect an instrument to operate correctly at all times. However, they are a decided improvement over humans in this respect. Where the operation cannot be easily checked by the operator as though the instrument were not there, a second independent instrument should be used to indicate when something is wrong. The operator can then gage his procedure accordingly.

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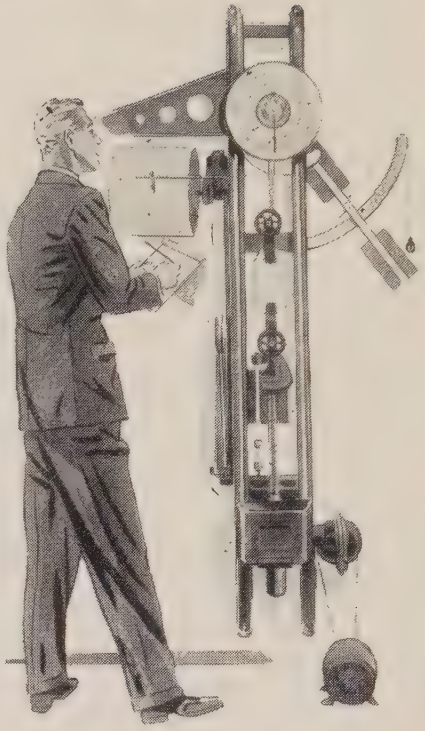

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Application and cost requirements dictate the type of instrument to be used. Application should be considered paramount to cost in considering an instrument for a specific fine control use. For a coarse control, any sturdy instrument that will fit the application should be good enough. However, a proper type instrument for the desired installation is essential.

Now, in going into the instrumentation used, I will not state the specific application for each use of an instrument, nor will I state the specific instrument used for each application to be mentioned. The inference in most cases should suffice.

I am sorry that I am not too well qualified to speak on instrumentation in electric power or in steam. These are two efficient departments handling their own instrumentation. In reference to the electrical applications, much has been done. The use of high-voltate a.c. selsyns, induction controls, control transformers, compensating rheostats, etc., is very common at the mill. Indicators and records seem to be everywhere.

In reference to steam, Hagan instruments and controls are in general use. The steam plant has two 400 p.s.i. superheat boilers, four 130 p.s.i. boilers, and one 175 p.s.i. boiler. These feed into a common 130 p.s.i. well. One 400 p.s.i. and the 175 p.s.i. boiler produce at constant rate. The production of steam from the other five boilers is controlled automatically by steam demand of the well. Any steam to the well from the high-pressure boilers is desuperheated automatically. Any excess steam not used by the generator-turbine is automatically by-passed to the well. Steam to the 175 p.s.i. generator-turbine is controlled and desuperheated automatically.

As probably everyone here knows, steam and power consumption by a mill is not a constant on an hour-to-hour basis. The application of instrumentation, as stated, has not only given operational ease, but also appreciable savings in fuel and man power.

CO_2 in flue gases is measured and recorded by a Ranareau-type instrument. The use is operational.

Steam flow to the various parts of the mill is measured by a recorder using remote control and a plate or Venturi-type orifice. Steam feed controllers, reducing valves, and pressure gages are common throughout the mill.

Steam to machine driers is regulated by a Stickless tension-control on most of the machines. However, one aft-drier section is using a Foxboro temperature recorder-controller with pressure indicator, together with a Hagan manual-control setting.

Steam headers to machine turbines and drier headers are equipped with pressure or temperature recorders. These recorders give a record showing how the machine functions, or show if some equipment is out of order.

Now, to leave the electric power and steam departments and to continue. A big problem in any mill is maintenance. Much time can be saved, trouble anticipated, and repair time allotted by intelligent use of instruments. Pressure gages at strategic points in pipe-lines, across pumps, etc., together with periodic inspection by foreman can give good warnings of trouble. Recording instruments need not be used in most instances. Ammeter readings on motors, temperature indicators, and sight glasses for bearing oil, oil pressure indicators all help to serve this purpose, as well as do any instruments used primarily for other purposes.

An instrument of many uses in a mill is the liquid-level indicator, recorder, controller, or any combination of these. It may be of the float, bubbler, or diaphragm types. Some specific uses of the float are as follows: Slurry stock is dropped from a chest in one building to a chest in another building. The problem is to not overflow the chest and to ease operators' duties. A float, located at near-full in chest, by being raised a few inches causes an electric lamp to light in each department giving sufficient warning. In another instance the warning light proved not practical. Replacing them by klaxons gave the desired results. In a third instance, a float is being used, together with an electrical arrangement to automatically control the flow of fresh water to the fresh water tank. Very little supervision is needed. However, the tank is equipped with both a liquid level recorder and indicator; i.e., three independent instruments.

All the indicators and recorders are of the bubbler or diaphragm type. In some applications they are controllers. In many applications they are interchangeable. Some specific uses are:

1. As Controller—The liquid level in a particular operation must be maintained within narrow limits and a float is not practical. A diaphragm type liquid level unit, activating an electric controller varies the speed of a pump to control the liquid level.

2. Used Interchangeably (Either Bubbler or Diaphragm)—Recorders are used on Oliver saveall chests and are located near the saveall. It lessens material waste due to human-element control. Recorders are also used on the stock chest before and after refiners, chemical storage, filler storage, etc. The use is primarily operational.

3. Use Bubbler Type Only—Where recording instruments are at a considerable distance apart and are activated by one unit, the bubbler unit is used. They are not too accurate in this use, but good enough for many purposes. They are used on beater room sulphite chests. (One recorder in beater room, one recorder in sulphite screen room.)

For liquid level in chests having very viscose or high-density dispersions.

Also, in chests where a diaphragm would not be easily accessible for calibration, bubblers can be used.

4. Use Diaphragm Type Only—Where air is objectionable, as a recorder on the machine head box for human-element control (when and if necessary), the diaphragm type may be used.

For low liquid level recorders, such as in weir measurement, they are used together with automatic samplers of water wheel or vacuum-break type and a weir or venturi flume and a laboratory for the determination of white water waste, sulphite tailings, groundwood tailings, etc. I would like to mention here that a trial is being made using a DeZurick sampler from which both the composite sample and rate of flow are obtained. It seems to be good thus far. Such a sampler, together with a liquid-level recorder should be a nice combination.

The second most prevalent instrument is the pressure or vacuum instrument which has been mentioned. Pressure indicators are used on grinders, digesters, pneumatically loaded rolls in supercalenders, presses, etc. Where the indicators do not serve to solve the problem, replacing them by recorders or recorder-controllers often help. The same may be said of vacuum indicators on paper machine suction. It is sometimes handy to have a spare vacuum recorder. This recorder may be used to replace an indicator for as long a time as needed to tell its story. Then the recorder is replaced by the indicator, and the recorder moved to another location.

The third most prevalent instrument is for measuring temperature. The activating element may be a confined gas or liquid for lower range, thermocouple for middle range, or pyrometer for high range. They should be compensating for ambient temperature. Temperature instruments are used as drier-temperature indicators, as recorders in coating-color storage tanks, alum preparing and storage, size preparation, etc., as recorders for sulphite cooking, grinder pits, etc. In one cooking operation a Foxboro recorder-controller is coupled to a cam time-temperature controller. The control is excellent.

The fourth type of instrument is the motion recorder.

In general it consists of a lever-arm arrangement between a recording pen and a valve stem; or between a valve stem and a remote control if it is desired to have the recorder away from the valve-stem location. These instruments are used on the automatic valve-stem of Trimbey regulators, on the cone-setting screw of stock refiners, and on various valve-stems throughout the mill. The latter valves are, in general, those used as throttling valves in stock lines. The purpose is to give a record of setting instead of counting threads and hoping that someone does not change the setting, thereby overloading or underloading the pumps.

Another instrument being used for what might be called a secondary purpose is the ammeter. Used on motors of stock refiners, pumps, presses, supercalenders, etc., a recording ammeter can give a record of operation. Used with mixers, it can be used to indicate process changes.

Flow recorders, indicators, or controllers are used for other purposes than steam control. Rotometers are useful in metering flow of components such as alum, filler dispersions, etc., when they are being fed to the head box. Bowser-type flowmeters with Xactomount offer an excellent means of measuring set-volumes of water, size, etc. A Sparling meter is used to record the draw of fresh water to the paper mill. It is understood that the Sparling meters are used elsewhere to measure volumes of stock at low consistencies. A Fischer-Porter flowmeter with control of another variable is being tried on a sulphite stock line.

A Beckman-type pH meter activating a controller is used on the steam condensate line from the sulphite plant to bypass water that is too acidic.

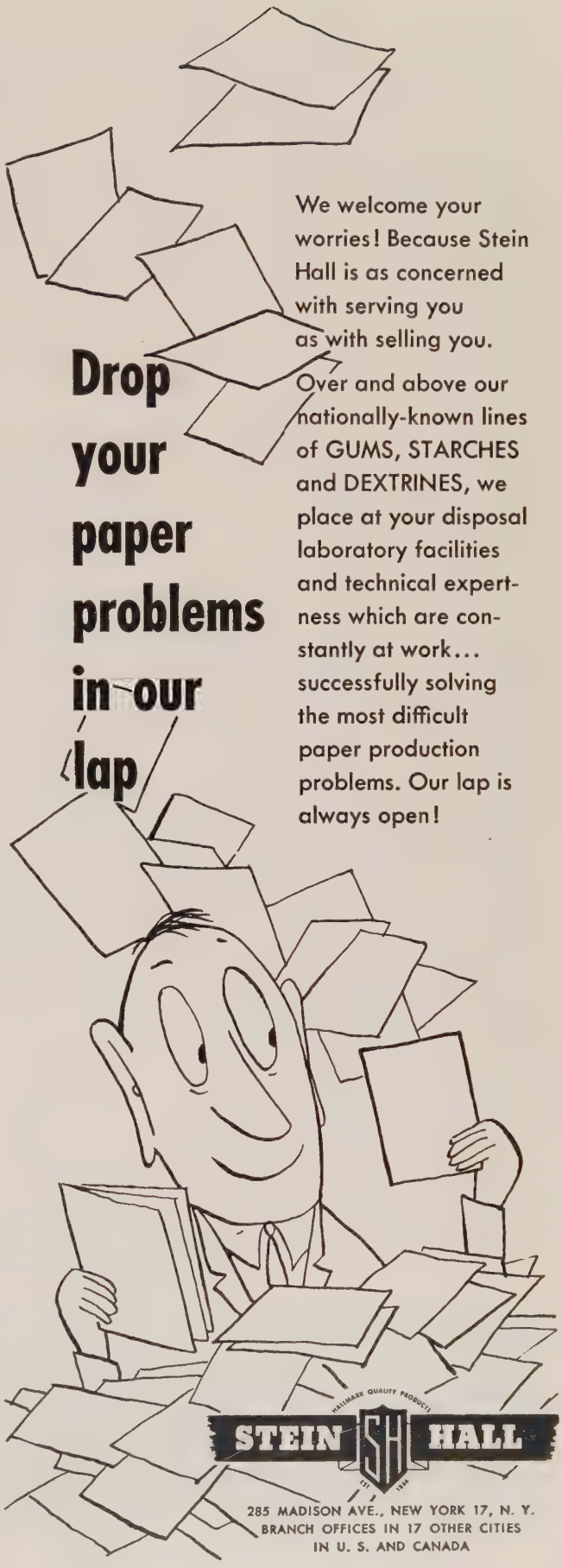
On paper machines, break-recorders and machine-speed indicators are in use. The break recorders are electrically operated and function by a brush against a calender roll. They work well, but are not human-proof. The speed indicators are relative. Speeds taken by laboratory personnel are used for calculation.

Sawdust from chippers is measured by means of a counterbalanced weigh meter and counter. It works well, but not human-proof.

Glossmeters are installed on some supercalenders. They are of the incident-light principle, recording on a Micromax. The readings are not as exact as laboratory tests. However, they serve the purpose well in aiding to solve the problems of variation in finish.

To show an application in which instrumentation is being used to solve an over-all problem in materials handling, we will consider clay handling. Clay is drawn from the car or bin by means of a Fuller airflow system and delivered to either the bins of weighhoppers. In one application, different clays may be drawn from one of two bins and delivered to weighhoppers. The weighhoppers are equipped with controllers that shut down the airflow system when a set weight of clay has been delivered. By means of manual reset, clay delivery can be shifted from weighhoppers to bins when drawing from the car, or it can be drawn to weighhoppers from bins. Therefore one man can unload cars to wherever desired by taking a few steps to push a button. By this means 40 tons of clay can be handled by one man in 4 to 12 hours, depending on the clay and operating conditions; or by two men if the clay packs hard. The weighhoppers and some pipes are equipped with vibrators to remove any clay that packs to the sides. Water for the mixing is measured by either a liquid-level gage in the mix tank or by a Bowser type flowmeter with automatic shutoff. Hence, a clay mix operation calls for not more than three men; and there is less dust, less dirt in clay, and much less demurrage.

An over-all application in operation is in the drying of coated paper. The paper goes through a forced hot-air drying unit of four sections and then over three conventional machine driers. Each hot-air section is equipped with a Foxboro temperature recorder-controller with man-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ual range setting, and a Verigraph foot is installed about two feet after the last drier and controls the steam to the driers. The Verigraph is also a recording type and has manual range setting. This application allows very good operation control.

An over-all application in finished product handling is on a belt carrying paper from sorters to trimmer. This may sound like a minor item but it has certainly helped solve a problem. This installation is an electric-eye device used to stop the belt when the beam is broken by a ream of paper. The activating light is on an arm which must be raised before removing the paper from the belt. Starting of the belt at the trimmer is manual. Therefore, the operation of the belt is by the trimmerman's helper. Only when the arm is up is paper placed on the belt. The operator must lower the arm and press the switch before the belt starts. He has a good view of the belt and its surroundings. Not only does this instrument stop the belt in the correct position each time, and gives a visual signal as to when the belt may be loaded, but two easy motions, instead of one, tend to cause the operator to glance up the belt before pushing the starting switch.

To go further would get us away from instrumentation and into methods. However, there is one which, although cited last, is far from least. This is the interdepartmental telephone. It is an installation from which savings in man power, material, and improvement in quality can be obtained in large quantity.

Two new instrument installations are going in soon: automatic control on one sulphite digester and an automatic SO_2 recorder. Others, we hope to install when the right instrument appears. It is very easy to overinstrument a mill. Processes and procedures change in time. Good instrumentation is an ever-present job. Installing instruments using manual controls, or manual controller settings is a good practice. Instruments need care and maintenance, and maintenance can be a problem with complicated instruments. However, the proper application of instrumentation to a given problem or series of problems can save material, horsepower, and manpower, increase efficiency, and give greater operational scope. It increases greatly the technical and mechanical control within a mill where the control data are properly correlated and interpreted.

Since some instrument manufacturers have been mentioned in this talk, it is only fair to say that in the steam plant, Hagan instruments are the most prevalent. Throughout the remainder of the mill Foxboro and Brown instruments account for a large percentage, and the remainder divided among several other makes.

Maine-New Hampshire

The TAPPI Maine-New Hampshire Section held its annual meeting at the Wentworth by the Sea, Portsmouth, N. H., on June 17–18, 1949.

The technical program was devoted to the general theme: "Additives in Paper Making." In this program the following papers were presented:

"Design of Wet End Additives to Paper," by I. J. Grundfest, Rohm & Haas, Philadelphia, Pa.
"Use of Gums, and Mucilage as Beater Additives," by J. W. Swanson, Institute of Paper Chemistry, Appleton, Wis.
"Modfying Paper Characteristics Through Chemical Additives," by Walter Morehouse, Nopco Chemical Co., Harrison, N. J.
"Why Size Paper," by J. P. Bainbridge, Jr., Mansanto Chemical Co., Everett, Mass.

The presentation of these papers was followed by a 3-hour panel discussion on the subjects presented.

At the business meeting the following officers were elected:

Chairman: John L. Parsons, Hollingsworth & Whitney Co., Waterville, Me.
Vice-Chairman: George P. Day, Brown Co., Berlin, N. H.
Secretary-Treasurer: H. E. Pratt, Pejepscot Paper Co., Brunswick, Me.

Executive Committeemen:
O. E. Anderson, International Paper Co., Chisholm, Me.
J. G. L. Caulfield, Eastern Corp., Bangor, Me.
R. S. French, Keyes Fiber Co., Waterville, Me.
A. P. Gregory, St. Regis Paper Co., Bucksport, Me.
C. I. Horton, R. T. Vanderbilt Co., E. Norwalk, Conn.
L. C. Jenness, University of Maine, Orono, Me.
A. E. Jones, Oxford Paper Co., Rumford, Me.
J. J. Thomas, S. D. Warren Co., Cumberland Mills, Me.
J. F. Wright, National Aniline Div., Boston, Mass.

Following the panel discussion on Saturday morning an old-fashioned clambake was enjoyed on the shore and the afternoon was devoted to sports. In the golf tournament Charles Pennings, of Williams-Gray Co., won low net and was followed by J. F. Kneeland of Arnold-Hoffman & Co. Other golf prizes went to Philip Bolton, Robert Gair Co., E. P. Ingalls, S. D. Warren Co., H. S. Chellis, Brown Co., and Sydney Hanks, Monsanto Chemical Co.

Comments on Technical Program

The general subject discussed at this meeting was the use of additives in the beater and/or on the paper machine for sizing purposes, wet strength, etc. Dr. Gruntfest of the Rohm & Haas Company gave an informal but very informative talk on wet-end additives to paper, emphasizing in particular the various urea formaldehyde resins made by his company. For instance, he suggested that Uformite 470 is probably best for sulphite papers and some advantage can be gained by first adding 470 and then following this with Uformite 467. The former is a cationic material while the latter is anionic in character. The urea polymer is heterogeneous in complexity. The statement was made that the wet-strength film is probably not continuous, especially if the resin is added to the beater or to the fibers before the sheet is formed. This film will be more continuous when the wet-strength resin is added in the size press. With respect to the relative effects of pH and electrolytes on urea formaldehyde resins, Dr. Gruntfest stated that the former is very effective while the latter is not significant in its effect.

Mr. Maxwell of the American Cyanamid Company commented on the fact that aluminum chloride and melamine resin give a higher wet strength than melamine and hydro-

Maine-New Hampshire Head Table Groups

Maine-New Hampshire Watermelon Fiesta

chloric acid. The melamine content of paper can be determined by analyzing for nitrogen.

In commenting on the Bardac process Mr. Maxwell stated that this has not reached the commercial stage at the present time.

The statement was made 5–10% wet-strength resin gives dimensional stability to paper and at the same time there is a reduction in the amount of beating required. The remark was made that 2% neoprene, added to the beater, also gives dimensional stability to paper.

In reply to a question concerning the relative merits of machine-drying versus air-drying of wet-strength treated paper, one of the speakers stated that in general air-drying gives a higher wet strength providing the paper is subsequently cured. Wet-strength resins give a greater degree of permanence to the paper in accordance with the TAPPI aging test but it was the opinion of Mr. Maxwell that this is a false test because of the fact that heating the paper gives an increased cure to the resin which results in a higher folding endurance and also alpha cellulose test. Furthermore, the viscosity test is not reliable in the presence of formaldehyde.

Considerable discussion was had on the subject of the reaction of formaldehyde or glyoxal with cellulose. This reaction tends to reduce water absorption and may stiffen the fiber. When added to starch, formaldehyde or glyoxal develops a greater degree of insolubility. If the degree of acidity of the formaldehyde treatment is sufficiently high it is probable that acetal formation occurs.

Dr. Newton of the Clinton Company commented on the proper way for preparing starch for beater addition. For best results the starch should be carried beyond the swelling point; a partial disintegration of the starch granules should occur. This is apparently accomplished by heating the starch to 93°C. for ten minutes (5% concentration). The order of addition of starch to the beater is recommended as follows: the starch dispersion is added after the rosin, a small amount of alkali is then added to a pH of 8.5–9.0. Alum is then added to the beater to a pH of 5.3–5.5. Gelatinized starches are available and when they are suspended in water they do not have the same effect as cooked starch. One man added that raw starch was added to the beater in his mill and this cooked satisfactorily on the driers as long as moisture content of the sheet was higher than 50% and the drier temperature was in excess of 160°F.

Dr. J. W. Swanson of the Institute of Paper Chemistry spoke on the use of gums as beater additives. Although Guar Gum is not available at the moment, Locust Bean Gum is now on the market and sells for about 30¢ a pound. One of the distributors is the Stein, Hall Company. 0.1% gum will improve fiber formation and 0.5% shows a marked improvement. This should be added after the refining operation. Natural gums reduce hygroexpansivity of paper, according to Dr. Swanson. High viscosity CMC also acts as a deflocculater for fibers but is more expensive than the mannogalactan gums. Furthermore, CMC is more sensitive to pH, alum usually being the precipitant. These natural gums act to inhibit or slow up the flocculation of fibers but do not prevent it. Furthermore, they give a degree of wet strength to paper. In the manufacture of toweling by the use of 1% gum it was possible to reduce the sulphite content of the furnish and obtain the same strength.

With respect to rubber latices, the comment was made that for economical reasons most of the usage would be limited to 2–5%, although this might increase for certain purposes to 15–20%. A saturated sheet does not give as good a fiber to fiber bond as the beater treated sheet.

Walter Morehouse of the Nopco Chemical Company presented an informative paper on modifying paper characteristics through chemical additives. The speaker com-

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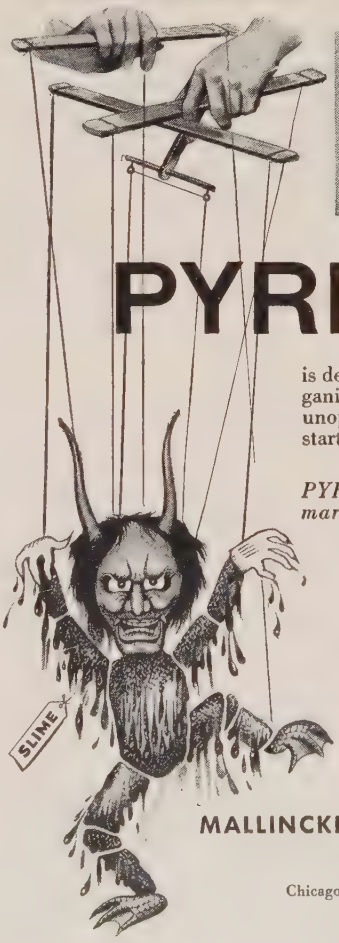

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mented on a talk given recently by Dr. Steenberg of Sweden on variables in paper machine operation, commenting on the fact that a well-formed sheet of paper stretched during the operation will have greater strength in the direction of starch. This information has been put into practice in Sweden by bag paper manufacturers who slit the paper at the wet end to enable them to take advantage of stretch which develops in the narrow strips in a more uniform manner than it would on the full width of the paper machine.

Mr. Morehouse discussed the application of rosin size to paper and said that rosin sizing may be expected to:

1. Impart water resistance.
2. Adversely affect sheet formation due to foaming.
3. Slightly increase paper stiffness.
4. Slightly lower bursting and tensile strength tests.
5. Improve the retention of dyes, pigments, and other chemical additives often used.

Next to beater size probably the most commonly used material is emulsified wax which is now obtainable in an anionic emulsion (having affinity for positively charged particles or surfaces), nonionic emulsion, and cationic emulsion (having an attraction to negatively charged particles). Pound per pound emulsified wax imparts greater water resistance than rosin soap. The use of wax alone or wax mixed with rosin size gives to paper the following properties:

1. Good water resistance to cold liquids.
2. Foam is greatly diminished and sheet formation aided.
3. Softness of the sheet is increased.
4. Bursting and tensile strengths are lowered.
5. Dimensional stability is improved.

A wax emulsion with the finest particle size obtainable, less than $\frac{1}{2}$ micron, is recommended for addition to the beater. For maximum retention the emulsion should be anionic to be reactive with the precipitant, alum. Best results are obtained when the wax emulsion is diluted to less than 5% solids before addition to the beater.

Another sizing agent, not too well known, is the sodium soap of a saturated high titer fat, such as sodium stearate. This product can be added to the beater and precipitated with alum in the same way as with rosin size. This type of sizing material is used in the manufacture of photographic paper. Thus a sodium soap of a saturated fatty acid can be utilized to impart the following characteristics to paper:

1. Water repellent characteristics.
2. Good dimensional stability.
3. Relative freedom from chemical activity.
4. Less than with rosin size.
5. Satisfactory sizing even at a pH of 10 at the time of sheet formation.

Mr. Morehouse described a polystyrene emulsion, recently developed by his company, having a solids content of about 42% and a pH of 9.5. The particle size is about 0.2 micron; it may be diluted to any desired concentration and has excellent stability to pumping action and agitation. It is immediately precipitated by the addition of alum. When added to cellulose fibers in the absence of alum and when the stock is on the alkaline side, very little reaction takes place and the emulsion disperses itself uniformly throughout the fiber mixture. On the addition of alum a fine precipitate develops, becoming coarser with time. If the emulsion is added to the fibers in the absence of alum, it is not necessary to predilute the emulsion. If the stock has been treated with alum, however, the emulsion should be diluted to about 1% solids to prevent too rapid precipitation. For satisfactory retention the pH of the stock must be lowered to 4.0 to 4.5. Retention is claimed to be high, over 90%.

Kalamazoo Valley

Kalamazoo Valley TAPPI Fun Day Committee
Left to right: John B. Verdon, American Cyanamid Co., K. Phillips, American Cyanamid Co., Don Knight, Bulkley, Dunton Co., Fred Van Streen, Price & Pierce Co., and Steve Kukolich, Lee Paper Co.

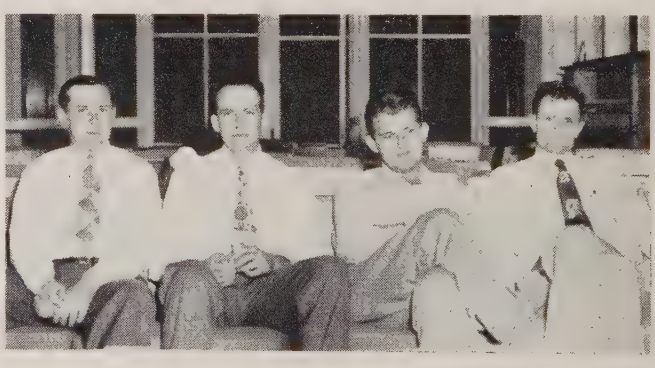
The annual fun day outing and annual election of officers of the Kalamazoo Valley Section was held on June 28, 1949 at the Gull Lake Country Club, near Kalamazoo, Mich.

The afternoon was given over to golf and shuffelboard games by the various men. Bogus money was supplied to all with registration and prizes were given in the evening to the winners of golf and the highest money winners.

Dinner was served at 6:30 p.m. in the Club House to approximately 160 people. After the dinner, the election of officers was held and the meeting turned over to John B. Verden, American Cyanamid Co. who was *Chairman* of the "Fun Day" Activities. Prizes were distributed.

The following officers were elected for the coming year:

Chairman—Stephen I. Kukolich, Lee Paper Co., Plainwell, Mich.
Vice-Chairman—James J. Harrison, Michigan Carton Co., Battle Creek, Mich.
Secretary—Victor S. Burnstein, Michigan Paper Co., Plainwell, Mich.
Treasurer—Fred L. Schucker, Hercules Powder Co., Kalamazoo, Mich.



New Officers, TAPPI Kalamazoo Valley Section
Left to right: Fred L. Schucker, *Treasurer,* Victor S. Burstine, *Secretary,* James J. Harrison, *Vice-Chairman,* and Stephen I. Kukolich, *Chairman.*

Maine-New Hampshire Fall Meeting

The Maine-New Hampshire Section will hold its fall meeting at the Lafayette Hotel, Portland, Maine on October 21–22, 1949. The program will be published in the September issue of *Tappi.*

EMPLOYMENT SERVICE

Individuals who have indicated a desire for employment should remember to advise *Tappi* by the 10th of each month if they desire to have their request for a position repeated or revised in any way. Applicants should prepare their own statements. Some requests arrive in the form of long letters which are difficult to condense to the length of statement such as appears below.

There is no charge made for these advertisements.

Positions Wanted

E31-49. Mechanical engineer. 28 years' diversified experience as designer, works manager, chief engineer, director of research, and consultant. 10 years in printing industry.

E32-49. Seasoned executive. 20 years of experience in production, research and technical sales. Seeking position where competence, trust, and unusual ability are required.

E33-49. Chemical engineer. 31, family, experienced in paperboard development and problem work. 7 years' diversified experience. Seeks more responsible position.

E34-49. Chemist. Paper technologist with engineering experience. 33, B.A. Chem. 10 years' research and 2 years' industrial experience, including quality control and statistical analysis.

E35-49. Plant manager in converting field. 46. College graduate. At present manager bag factory. Experience in paperboard manufacture and coatings, laminating.

E36-49. Chemist. Young woman, B.S., 6 years' experience in paper converting and general application research. Knowledge of adhesives, coatings, lacquers, plastics. Desires connection with firm interested in quality control and packaging development.

E37-49. Development chemist, 41, family, Ph.D. 15 years' industrial experience in paper and dissolving pulps, plastics, fiberboard, and waste wood utilization.

E38-49. Research director. Ph.D. phys. chem. 14 years' experience dissolving pulps, byproducts, heavy chemicals. Product and Market development.

E39-49. Chemist for plant control and production problems. Kraft mill in Virginia.

Positions Open

P10-49. Development engineer. College graduate. Corrugated containers and container testing in large corrugated box plant in Southeast. Several years' experience in design, evaluation, and manufacture of corrugated containers required. Address P. O. Box 1828, Savannah, Ga.

P15-49. Head quality control group or be a consumers' representative. Must thoroughly understand facial tissue quality. Northeast.

P16-49. Technical director. Experience in cellulose wadding, facial and other tissues. Northeast.

P17-49. Research and development. Cylinder board papers, furnishes, coatings, resins. 5–10 years' research and plant experience necessary.

P18-49. Sales engineer, experienced, to cover mills from Wisconsin to Atlantic Seaboard for well-established manufacturer. Spend half-time traveling. Car furnished. Salary and commission plus expenses.

P19-49. Analytical chemist. Control laboratory. Paper mill. Northeast.

P20-49. Research chemist. Recent Ph.D. with experience in experimental and theoretical carbohydrate, and specifically cellulose chemistry. Philadelphia.

P21-49. Chemical engineer. A few years' pulp and paper mill experience, including laboratory and plant. Northeast.

P22-49. General manager and superintendent. Corrugated packaging, paper and folding carton converter in East. At least 10 years as works manager with experience in purchasing, cost control, and specialty sales. Age 38–45.

P23-49. Chem. Engr. with some pulp mill experience for technical sales to pulp and paper mills.

P24-49. Young man capable of handling the technical end of making shoe innersole board containing latex. Part time selling and servicing board on road.

P25-49. Pulp mill tour foreman. Bleached and unbleached kraft. Middle West.

P26-49. Works manager. Under 50. Who has had charge of folding carton or corrugated box plant. Plant in New England.

Photo, Courtesy J. M. Huber Corporation

Single Instrument Measures Smoothness, Porosity and Softness of Paper

You just interchange the lower test plates in the GURLEY-HILL S-P-S Tester to convert it into an instrument for testing either smoothness, porosity or softness of any type of paper, by measuring a given air-leakage over or through the paper.

This 3 in 1 laboratory "assistant" is simple to operate, quick and accurate, and a real utility instrument where printing quality of paper must be reliably measured.

Bulletin No. 1400 describes the S-P-S Tester as well as other Gurley paper testing instruments. It's worth writing for today. W. & L. E. Gurley, Station Plaza & Fulton St., Troy, New York.

NOW 3 NEW MEMBERS OF THE ARWAX FAMILY OF WAX ADDENDS

ARWAX POLYETHYLENE CONCENTRATES

For grease-resistance and gloss PLUS higher blocking temperature . . . higher tensile strengths.

Recommended Uses

— Bread Wrappers . . . Milk Carton Wax . . . Greaseproof Cartons.

ARWAX BUTYL RUBBER CONCENTRATES

Similar to ARWAX Vistanex concentrates but lower cost and easier to handle . . . Improves adhesion and flexibility of paraffin and microcrystalline waxes.

Recommended Uses

— For improved wax laminations . . . for milk carton coating . . . in wax coatings for deep freeze cartons.

ARWAX S-POLYMER CONCENTRATES

Provide drier, harder and less rubbery wax coatings, than do Vistanex or Butyl rubber addends. Flexible . . . raise blocking point . . . improve tensile, decrease MVTR.

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GENERAL OFFICES: 103 FOSTER STREET · PEABODY · MASSACHUSETTS

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Resin Emulsions, Solutions and Hot Melts for Adhesive Bases, Binders, Coatings, Sizes and Saturants

PERSONAL MENTION

Items About New and Old Tappimen

New TAPPI Members

Kenneth M. Battenfield, Technical Sales Service, Anheuser Busch, Inc., Corn Products Div., St. Louis, Mo. Attended Illinois Technical Institute and Northwestern University.

Chester T. Beals, Technical Assistant to Paper Mill Superintendents, Crown Zellerbach Corp., Camas, Wash., a 1934 graduate of the University of Washington.

Russell F. Clark, Chief Chemist, Newton Falls Paper Mill, Inc., Newton Falls, N. Y., a 1947 graduate of the University of New Hampshire with an M.S. degree.

Paul N. Clemens, Sales Engineer, Lithgow Corp., Norwalk, Conn.

George E. Field, Technical Service Manager, B. F. Goodrich Chemical Co., Cleveland, Ohio, a 1931 graduate of Case Institute of Technology.

Thomas Gerace, Sulphite Superintendent, St. Regis Paper Co., Deferiet, N. Y., a 1936 graduate of Clarkson College.

Philip H. Glatfelter III, Executive Vice-President, P. H. Glatfelter Co., Spring Grove, Pa., a 1938 graduate of Brown University.

Walter H. Hall, Mechanical Engineer, Mead Corp., Chillicothe, Ohio, a 1927 graduate of the University of Kansas.

E. Hemlin, Director of the Library, Chalmers University of Technology, Gothenburg, Sweden.

Herbert L. Hergert, Student, Institute of Paper Chemistry, Appleton, Wis., a 1948 graduate of Reed College.

Gustaf Jacobsen, Cost Engineer, St. Regis Paper Co., Oswego, N. Y., a 1946 graduate of the University of Gothenburg with an M.S. degree.

Abdul H. Khan, Deputy Director, Planning and Development, Government of Pakistan, Karachi, Pakistan.

Cecil G. Killam, Research Chemist, British Columbia Pulp & Paper Co. Ltd., Woodfibre, B. C., Canada, a 1940 graduate of the University of British Columbia.

Clarence B. Kinney, manager, Textile Sales, E. F. Houghton & Co., Philadelphia, Pa., a 1909 graduate of Pratt Institute.

Raymond D. Kolasinski, Chemical Engineer, John Strange Paper Co., Menasha, Wis., a 1948 graduate of the University of Wisconsin.

James D. Lindsay, Professor and Head of Chemical Engineering Dept., A. & M. College of Texas, College Station, Tex., a 1924 graduate of the University of Michigan with an M.S. degree in 1925 and a Ph.D. degree in 1934.

Allen A. Lowe, Sales Promotion Manager, The Sandy Hill Iron & Brass Works, Hudson Falls, N. Y.

E. David McKay, Technical Assistant, Institute of Paper Chemistry, Appleton, Wis., a 1947 graduate of Centenary College of Louisiana.

Robert J. Meagher, Director of Research, Folding Paper Box Assn. of America, Chicago, Ill., a 1931 graduate of the University of Southern California.

John A. Miller, Assistant Superintendent, Container Corp. of America, Wabash, Ind., a 1942 graduate of Purdue University.

Haldar Ottar, Chemical Engineer, A/S Viul, Tresliperi, Viul, Norway, a 1947 graduate of the Royal Institute of Technology, Sweden.

Juan E. Phillips, Graduate Student, New York State College of Forestry, Syracuse, N. Y., a 1946 graduate of Santa Maria University, Chile.

William B. Stengle, Chemist, Crossett Lumber Co., Crossett, Ark., a 1949 graduate of New York State College of Forestry, Syracuse, N. Y.

Godfrey R. Van Kampen, Sales Manager, Red-Ray Mfg. Co., Inc., New York, N. Y. Attended Hope College.

Leslie Velossy, Technical Librarian, Lion Oil Co., Research Div., El Dorado, Ark.

George E. Weinman, Plant Engineer, Bloomer Bros. Co., Newark, N. Y., a 1918 graduate of the Rochester Institute of Technology.

David Wetherhorn, Shift Chemist, Southern Paperboard Corp., Port Wentworth, Ga., a 1941 graduate of Vanderbilt University.

John M. Wilcox, Manager, Sales and Engineering Dept., Electric Steel Foundry Co., Portland, Ore., a 1931 graduate of the University of Washington.

Robert H. Winter, Chemist, Grand River Paper Corp., Grand Rapids, Wis., a 1937 graduate of Hope College.

Edward A. Wodka, Control Engineer, Lowe Paper Co., Ridgefield, N. J., a 1948 graduate of Columbia University.

TAPPI Notes

E. Clinton Ash, Jr., chemical engineer, Crown Zellerbach Corp., has been transferred from Camas, Wash., to Port Townsend, Wash.

Bertram W. Barrows, formerly with the Gould Paper Co,. is now chief chemist for the Racquette River Paper Co., Potsdam, N. Y.

Howard W. Bartlett, formerly of Sitroux, Inc., is now owner of Neltex Aprons, 11 Broad St., Utica, N. Y.

Alexander F. Brobesky, formerly of the N. Y. State College of Forestry, is now with the Mengel Co., Fulton, N. Y.

Geoffrey Broughton, formerly asst. superintendent of the Paper Service Dept., Eastman Kodak Co., is now head of the Pulp and Paper Technology Dept., recently established at the Lowell Textile Institute, Lowell, Mass.

Wallace W. Brown, formerly with the Sorg Paper Co., Ltd., is now with Consolidated Paper Co., Grand Mere, P. Q.

Walter J. Bublitz, Jr., formerly of the Institute of Paper Chemistry, is now with the Lithographic Technical Foundation, 1800 S. Prairie St., Chicago, Ill.

Chas. J. Campbell, staff process engineer, Kimberly-Clark Corp., is now with the Coosa River Newsprint Co., Coosa Pines, Ala.

Bert L. Channer, formerly of the N. Y. State College of Forestry, is now in the service department, H. Waterbury & Sons, Co., Oriskany, N. Y.

Alfred P. Coha, student, N. Y. State College of Forestry, is working this summer in the Research Laboratory, American Viscose Co., Marcus Hook, Pa.

Robert E. Collins, formerly of the N. Y. State College of Forestry, is now chemist for the West Virginia Pulp and Paper Co., Mechanicsville, N. Y.

E. E. Ditterline, formerly of the Byrne Organization, is now mechanical engineer for Almirall & Co., Inc., 53 Park Place, New York, N. Y. (Heating, Ventilating and Air Conditioning).

Philip C. Evanoff, formerly of Dill & Collins Division, is now in the Sales Service Department, Mead Corp., Chillicothe, Ohio.

Fred W. Farrell has retired as Secretary and Technical Director of McLaurin-Jones Co., Brookfield, Mass., but will

continue as a consultant and director of the Company.

James E. Foote, formerly of the B-F-D Div., Diamond Match Co., is now general manager, E. B. Eddy Co., Hull, P. Q.

William J. Hall, formerly of the N. Y. State College of Forestry is now project chemist, Weyerhaeuser Timber Co., Kraft Mill, Springfield, Ore.

Charles L. Haug, formerly Manager of Production, Anton J. Haug, Inc., is now asst. manager, Lynch-Dutchess Lumber Co., Beacon, N. Y.

Frank E. Hill, formerly of the N. Y. State College of Forestry, is now chemist, Union Bag & Paper Corp., Hudson Falls, N. Y.

Victor R. Johnson is now pulp mill superintendent, Central Paper Co., Muskegon, Mich.

William H. Kraske, formerly of the Gould Paper Co., is now supervisor of sulphite mill, groundwood mill, and bleach plant, Oxford Paper Co., Rumford, Me.

Myron G. Kuhlman, formerly of the Ohio Boxboard Co., is now technical director, Fleming & Sons, Inc., Dallas, Tex.

James A. Lee is now Southwestern Editor, *Chemical Engineering,* Houston, Tex.

Milton Litvin, formerly of West Virginia University, is now a graduate student in the Chemical Engineering Dept., Ohio State University.

Frederick E. Macy, formerly of A. M. Collins Co., is now Manager, Specialty Div., H. G. Craig & Co., Inc., 230 Park Ave., New York, N. Y.

Hugh D. Nickel of Combustion Engineering-Superheater, Inc., is now District Manager, Skinner Bldg., Seattle, Wash.

Roland A. Packard, formerly of the Bagley & Sewall Co., is now Executive Vice-President and General Manager, Holyoke Machine Co., Holyoke, Mass.

Thomas E. Palmer, formerly of Reynolds Metals Co., is now with St. Regis Paper Co., Deferiet, N. Y.

Miss Josefina Peraza has returned to Mexico City where she is a chemist in the National Bureau of Standards. She has been a guest worker at the Washington Bureau for several months.

C. Curtis Phelps, formerly of the N. Y. State College of Forestry, is now chemist for the Brownville Paper Co., Brownville, N. Y.

Bernard F. Smith, project engineer, Kimberly-Clark Corp., is now with Coosa River Newsprint Co., Coosa Pines, Ala.

H. Scott Smith, formerly of the Central Paper Co., is now pulp mill tour foreman, Fibreboard Products, Inc., Antioch, Calif.

John Studeny is now supervisor of technical paper sales, Hammermill Paper Co., Erie, Pa.

George Vamos is now Chief, Paper Research Institute, Budapest, Hungary.

Harry E. Weston, Associate Secretary-Treasurer, Am. Pulp & Paper Mill Supts. Assoc., recently was awarded the George Arents Pioneer Medal by Syracuse University for advancement of industrial education.

William Whiting, Jr., formerly of the Univ. of Maine, is now with the Whiting Paper Co., Holyoke, Mass.

Edgar Wiberg, formerly of the Central Paper Co., is now paper machine tour foreman, Pulp Div., Weyerhaeuser Timber Co., Springfield, Ore.

A. M. Worthington, formerly of the American Tissue Mills, is now chemist, Champion-International Co., Lawrence, Mass.

J. Howard Wright, formerly of the St. John Sulphite Co., is chemical engineer, W. C. Hamilton & Sons, Miquon, Pa.

* * *

Prabodh J. Patel has been appointed official corporate representative of the Gujarat Paper Mills Ltd., Almedebad, India, in TAPPI.

Lawrence Gussman, Vice-President for Stein, Hall & Co., has succeeded J. R. Adams as official representative in the Technical Association.

* * *

Recent visitors from Europe include:

Georg Haindl, consultant, Augburg, Germany.

Guilio Consiglio, technical consultant, Cellulose d'Italia, Rome, Italy.

F. A. Oetken, Secretary, Lurgi Gesellschaften, Frankfort am Main, Heddernheim, Germany.

Industry Notes

The New England Spectrochemical Laboratories of Ipswich, Mass., has purchased the outstanding stock of Skinner & Sherman, Inc., Boston, Mass. The two companies will continue to operate independently with the present officers.

* * *

American Bitumels Co. has established a new office at 600 S. Michigan Ave., Chicago, Ill. E. M. Lorenzini, Manager of Bitusize Sales and official company representative in TAPPI, will be located at this address.

* * *

Dorr Co., 570 Lexington Ave., New York 22, N. Y. has recently issued an 8-page, 2-color leaflet entitled "Dorr Equipment and Methods for Modern Water Pre-Treatment." It includes flow diagrams and basic design data for plant units treating various types of water.

* * *

Shartle Bros. Machine Co., Middletown, Ohio, recently issued a Bulletin No. 7-SB (12 pp.) on the subject of Hydrafiners. It contains interesting test data.

* * *

Taylor Instruments Companies, Box 111, Rochester 1, N. Y., has just issued a 60-page bulletin, designated as Form 98040 covering "Instrument Applications for Wood Pulp Paper Processing." It is, in effect a monograph covering grinders, digesters, sulphur burners, gas coolers, lime slakers, evaporators, causticizers, washers, bleachers, beaters, press rolls, driers, calenders, and other applications. It is well illustrated and is an excellent data reference publication.

Harold Clyde Kinsey

Harold Clyde Kinsey, President, Cameron Machine Co., Brooklyn, N. Y., died at his home in Brooklyn on June 25, 1949, following a long period of illness.

Mr. Kinsey was born in Philadelphia, Pa., in 1882 and spent most of his life in the publishing business, first with John Wanamaker in Philadelphia, then with Doubleday, Page & Co., and later with the Cosmopolitan Book Co., and finally with the company that bore his name. He sold his business in 1943 to G. P. Putnam & Sons so that he could devote his entire time to the Cameron Machine Co.

Robert Bell-Irving

Robert Bell-Irving, Vice-President, Powell River Co., Ltd., Powell River, B. C., died at his home in Vancouver, B. C., on July 3.

Mr. Bell-Irving was born at Vancouver, B. C., on July 30, 1893, and graduated from McGill University as an engineer in 1914. From 1914 to 1918 he was overseas with H.M. Overseas Forces. He joined Powell River Co. in 1920 as an assistant engineer, becoming mill manager in 1926.

He was a member of the Executive Committee of the Technical Association of the Pulp and Paper Industry from 1929–31.

Wet Tensile Breaking Strength of Paper and Paperboard

(Revision of TAPPI Tentative Standard T 456 m-44)*

THIS METHOD is suitable for the determination of the tensile strength of paper and paperboard after complete saturation with water. The results are of special importance in the testing of paper towels, blueprints, bags, moist-food wraps, etc., that are subjected to stress after being moistened.

DEFINITION

The wet tensile breaking strength of paper is here defined as the tensile strength of the paper after complete saturation with water. Complete saturation is defined as exposure to water until the specimen is wetted throughout and a stable minimum strength value is obtained.

Note: Factors other than degree of saturation may cause further loss of strength after extremely long periods of soaking (usually days or weeks). Such factors include slow hydrolysis of any wet-strength agent that may be present, and bacterial action on the fiber itself. Even though these factors may be very important, they are outside the scope of this method.

If the tensile strength of a paper is measured before it is completely saturated, the results obtained shall be identified as "tensile strength after . . . minutes soaking in water," in which the time of exposure is specified. Such results are to be distinguished from "wet tensile strength" as defined in this test.

If a liquid other than distilled water is used, the results shall be reported as "tensile strength after . . . minutes exposure to . . .," and both the time and the liquid shall be specified. Again, such results are to be distinguished from "wet tensile strength" as defined in this test.

APPARATUS

1. *Tensile Tester* as specified in TAPPI Standard T 404 m. If the paper is very weak, remove the detachable weight and its pin from the pendulum and recalibrate the instrument as therein specified.

The pendulum type tensile tester may be modified by the attachment of a *Finch Wetting Device.* This attachment consists of a stirrup about 1.5 inches wide and 3 inches long, made of two metal straps which support horizontally a cylindrical rod, $^3/_{16}$ inch (5 mm.) in diameter and a little more than 1 inch long. Between the straps is a small vertically movable container for holding water. The liquid container locks in the uppermost position, so that the horizontal rod is immersed in the liquid to a depth of at least 0.75 inch. A metal tongue at the bottom of the stirrup permits it to be clamped in the lower jaw of a tensile tester.

2. *Blotting Paper.* That specified in TAPPI Standard T 205 m is suitable.

TEST SPECIMEN

The specimens for test shall be conditioned at 23°C. and 50% relative humidity before strips are cut accurately and parallel in each principal direction of the paper, and over 120 mm. (preferably 150 mm.) long. The width shall be 12.7 mm. (0.5 inch), 15.0 mm. (0.59 inch), 25.4 mm. (1.0 inch), or 50.8 mm. (2.0 inches). They shall be selected so as to be representative of the sample.

PROCEDURE

The test shall be made in accordance with the procedure given in TAPPI Standard T 404, using strips that have been saturated with water (distilled or equivalent) having a temperature of 23 ± 2°C. At least 10, and preferably 20, strips cut from each principal direction of the sheet shall be tested.

Determine the time required for complete saturation by immersing test strips for various periods and determining their tensile strength at the end of each period until no further significant loss in tensile strength occurs. (Tests on five strips cut in one direction of the sheet, preferably the machine direction, are sufficient for these preliminary tests). The maximum time so found should be used as the *minimum* time of immersion for the final test.

Note: For heavy papers or paperboard that are difficult to saturate, it may be necessary to make preliminary tests after immersion for 2, 4, 8, 16, and 24 hours. In such preliminary tests the increase in time intervals should be sufficient to be determinative. In general, each succeeding interval should about double that of the previous one.

To saturate materials that can be handled without difficulty when wet, wholly immerse each test strip in a shallow dish of water. After complete saturation (time of saturation will vary greatly depending on caliper, sizing, etc.), withdraw the strip, lay it flat and straight on a pad of blotting paper, cover with a sheet of blotting paper and press lightly to remove excess water. Test immediately.

To wet materials which are relatively flexible and relatively absorbent, bend the test specimen slightly and touch the apex of the curve to the surface of water in a suitable vessel in such a way that the

* This revised method has been approved as a tentative standard by the Wet Strength Committee. Criticisms are earnestly requested and should be sent to R. G. Macdonald, Secretary, Technical Association of the Pulp and Paper Industry, 122 E. 42nd St., New York 17, N. Y.

wetted area extends at least 1 inch and not more than 1.5 inches lengthwise of the strip and is uniform across the width of the strip. Remove excess water from the test specimen by touching the wetted area to a blotter or other absorbent surface. Immediately insert the test specimen into the tensile tester so that the jaws are clamped to the dry areas of the strip with the wet area approximately midway between; then determine the tensile strength in accordance with TAPPI Standard T 404 m.

The Finch device may be used for testing flexible, absorbent papers for wet strength. In addition, it may be useful in certain use tests where wetting periods of short duration are desired. Where the Finch device is used, clamp it in the lower jaw of the tensile tester. Place the liquid container in its lowest position and nearly fill it with water. Loop the dry test specimen under the dry horizontal rod and clamp the two ends of the specimen in the upper jaw of the tensile tester. Raise the liquid container so that it locks in its uppermost position, thereby immersing the looped end of the specimen to a depth of at least 0.75 inch. At the end of the immersion period, proceed with the test with the liquid container in its uppermost position. The indicated strength is divided by 2 to obtain the wet strength of a single strip.

REPORT

Results obtained on strips cut in the machine direction shall be reported as wet tensile strength, machine direction, and results obtained on strips cut in the cross direction shall be reported as wet tensile strength, cross direction. The average value of the breaking load results shall be reported in kilograms per 15 mm. width, or pounds per inch width, to the nearest 2% of the total reading. (Kg. per 15 mm. $\times$ 3.73 = pounds per inch). The average, maximum, and minimum wet tensile strength for each of the principal directions of the paper shall be reported. Report also the time of immersion and the number of strips tested for each direction. In addition, report the wet tensile strength as a percentage of the usual (dry) tensile strength as determined by TAPPI Standard T 404 m.

Weight-Volume Measurements of Pulpwood and Chips*

(*Revision of TAPPI Tentative Standard T 7 p-45*)

For pulpwood, in addition to the usual estimations of density, moisture, bark, etc., usually a determination of the quantity of wood per commercial unit of volume is desirable. Two methods, a dry method (A) and an immersion method (B), are described below for determining the volume of wood and weight of dry wood per laboratory racked cord. In addition, methods are given for comparing the value so obtained with commercial scaling of pulpwood.

METHOD A

Apparatus

1. *Four-foot cord rack,* 8 feet long, with ends 4 feet high and not less than 3 feet wide, open at the top, front and back, strongly braced and furnished with projections whereby a string can be stretched between the tops of the end members at a distance of 6 to 8 inches in front of the rack.
2. *Platform scale,* either one of about 250 pounds maximum capacity, for weighing individual logs, or one of 3 or 6 tons maximum capacity, for weighing the whole cord.
3. *Saw.* Preferably a power-driven circular saw about 30 to 40 inches in diameter.
4. *Hook Rule.* A rule of wood or metal with a metal arm at one end which can be turned at right angles to the extended rule, forming a hook which automatically sets the zero-point of the rule at the end of the log.
5. *Steel tape,* to read average diameter from the circumference measurement.
6. *Storage Containers.* Closed containers for storing disks while testing. Ten-gallon covered garbage cans are convenient for this purpose.

Test Specimen

The sample shall consist of not less than 2 cords nor less than 0.1% of the total shipment, selected at random. If removed from a large pile, take care that the sample is as representative as possible.

Procedure

Unless the wood is in approximate 4-foot lengths (which will be measured exactly later), measure and record the actual lengths of about 20 logs selected at random. If the wood is in approximate 8-foot lengths, cut a uniform length (for example, 48 inches) from each log. If the wood pieces were originally about 4 feet, omit this step.

Systematically rack the wood into the laboratory cord rack, taking care that the wood is neither too loosely nor too closely packed. When the rack is nearly filled, stretch a string between the two end members of the rack, at the exact height of their top and 6 to 8 inches in front of them. Carefully level off the rack by unselectively adding logs until there are logs which extend above the string to an extent which approximately balances the voids in the top layer below the string.

Mark the wood which is to be removed for further sampling by the following procedure. Stretch a string between the centers of the logs on opposite corners,

* This recommended practice has been approved as a tentative standard by the Fibrous Materials Testing Committee. Criticisms are earnestly requested and should be sent to R. G. Macdonald, Secretary, Technical Association of the Pulp and Paper Industry, 122 E. 42nd St., New York 17, N. Y.

diagonally across the face of the cord of wood. Beginning with the log in the corner, number consecutively along the string each log whose center is within a distance from the string equal to the radius of the smallest log in the cord. Proceed across one diagonal in this manner, then across the other until the requisite number of logs has been selected (approximately 20% of the number in the cord). If this still does not give enough logs from the sample, stretch the string across other points on the face of the rack, for example horizontally or vertically through the center, and proceed with the selection in the same manner as above.

If desired for future reference, a photograph of the racked wood may be taken at this point. Figure 1 is a picture of a racked cord, showing part of the rack, the method of recording the log numbers, and the height to which the wood is filled into the rack. Superimposed upon this picture is shown the method of selection of the sample logs, black lines representing the path of the string and numbers in black (1 to 21) of the logs selected.

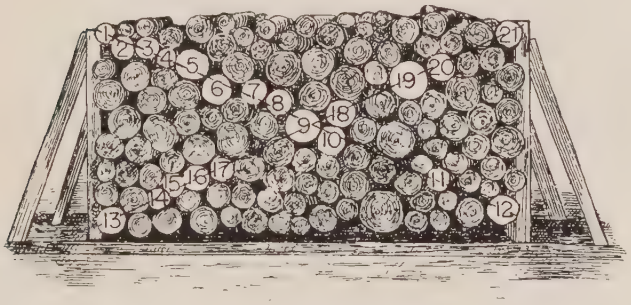

Fig. 1. Racked cord with numbered logs

Obtain and record the net weight of the entire cord as soon as possible, weighing either as a unit, or log by log, depending on the scale available, and separate the numbered (sample) logs from the remainder of the cord. By means of the hook rule, determine the lengths of the sample logs and record figures to the nearest quarter inch.

Saw one knot-free disk of uniform thickness (between $^3/_4$ and 1 inch) from each of the sample logs. From original 4-foot logs saw these disks at points 10 to 24 inches from either end; from original 8-foot lengths saw the disks from a section 5 to 24 inches from the freshly cut end. Number the disks and place them in an air-tight or nearly air-tight container.

With each disk proceed with the following steps as rapidly as accuracy allows, omitting (a), (b), and (c) for peeled wood:

(a) Remove a disk from the container and weigh and record the weight to the nearest 0.1 gram. (b) By means of the diameter-indicating tape, measure and record the average diameter. (c) Remove the bark from the disk. (d) Weigh the peeled disk and record the weight. (e) Measure and record the peeled diameter.

If it is necessary to interrupt the performance of the foregoing steps, return the disk to the container until the testing is resumed. Store the disks in the air-tight container prior to determination of density. Determine the average green- and dry-wood densities and moisture content of the bark-free disks in accordance with TAPPI Standard T 18-m.

Calculations

From the data obtained on the sample disks, calculate and record, in addition to the specific gravity and moisture, the following:

(1) Average diameter (barked), to 0.1 inch.
(2) Range of diameters (barked), maximum and minimum.
(3) Percentage of bark:
  (a) By weight. This is 100 times the difference between the total weights of the disks before and after barking, divided by the total weights before barking.
  (b) By volume. From the measured diameter obtain the area of the cross section of each disk (both rough and peeled). Total the areas of the unbarked cross sections, subtract the total area of the barked cross section, and divide by the total rough-section area. The quotient, times 100, gives the percentage of bark by volume.

From the data obtained on the racked wood calculate the following:

(1) Total gross weight of wood per cord of 128 cubic feet.
(2) Average length, which is the arithmetical average of the lengths of the sample logs. (If desired, also calculate the percentage of logs over and/or under standard.)

From these values calculate:

(3) Volume per cord of peeled green wood in cubic feet at time of racking. This is equal to:

$$\frac{W\ \dfrac{(100-B)}{(100)}\dfrac{(100-M)}{(100)}}{D}$$

where

W = weight per cord of unbarked green wood
B = bark as percentage of the green weight
W = moisture as percentage of the green weight
D = density based on moisture-free weight, green volume

(4) Volume per cord of unbarked green wood at time of racking. This is equal to:

$$\frac{\text{peeled volume} \times 100}{100 - \%\ \text{bark by volume}}$$

(5) Weight of oven-dry wood per cord. This is the volume of peeled green wood times the density based on moisture-free weight and green volume.

Report

Report the following to three significant figures:
Total gross weight of wood per cord, in pounds.
Average maximum and minimum diameter of bark-free logs, in inches.
Bark, percentage by green weight and by volume.
Actual length of logs and, if desired, the percentage of logs over (or under) standard.
Specific gravity based on moisture-free weight and green volume.

Density, in pounds per cubic foot (on moisture-free weight and green volume).
Moisture, percentage of green weight.
Volume per cord of unbarked green wood, in cubic feet.
Total dry wood per cord, in pounds.

Accuracy

The accuracy of this method depends on:

1. The adequacy and uniformity of the sample tested.
2. The uniformity of the density along the length of the logs of wood.
3. The uniformity of moisture along the length of the sample.
4. The accuracy of the procedures used.

The density at intervals 8 to 12 inches apart along the length of a stick of pulpwood may vary as much as 6 to 8%, depending on the presence of small knots, scars, etc. The moisture content may vary more; in green wood as much as 10% over the length of the stick. However, great as they are, both these variations are usually less than the variation in density and moisture from log to log, and are minimized by selecting a sample consisting of a minimum of 18 to 25 logs. No sample consisting of a lesser number should be considered as representative.

With ordinary precautions, the method of determining the density will result in an error of less than 1%.

METHOD B

Apparatus

The apparatus listed in items 1 to 6, inclusive, for Method A is also required for Method B. In addition are necessary:

7. *Barking equipment* for wood with bark (spud or draw knife and barking horses).

8. *Immersion tank* to hold about one fifth or more of a cord of 4-foot wood. This tank is provided with an overflow arrangement into a calibrated tank which is provided with a hook depth gage or other means for measuring displacement volumes.

Test Specimen

As for Method A.

Procedure

Proceed as described under Method A through the operation of sawing disks from the sample logs and storing them in covered containers.

Remove any bark from the disks and determine the moisture content according to TAPPI Standard T 18 m. Weigh the remainder of the logs from which the disks were cut. By means of the tape, measure the diameter at each end and record the average diameter. If unbarked, peel the bark from the logs, or use a draw shave. Weigh the peeled logs immediately after barking and record the weight; also measure the diameter at each end and record the average. Thoroughly wet the peeled logs by placing them under a spray of water for an hour or more. Finally, transfer the logs at once to the displacement tank, immerse, and determine their volume in cubic feet.

Calculations

With the exception of density and specific gravity, the calculations are the same as given under Method A.

Density. (a) On the basis of weight and volume as received. This is the total weight of the peeled logs from which the disks have been cut, divided by the total volume in cubic feet as determined by displacement. (b) On the basis of moisture-free weight and volume as received. This is (a) above, multiplied by (100 —% moisture), divided by 100.

Specific Gravity. This is the density on the moisture-free weight basis, (b) above, divided by 62.38.

Report

As for method A.

Accuracy

Results by Method B should compare closely with those obtained by Method A, except for very dry wood having radial cracks which are not taken into account with the first method.

Method B is probably slightly more accurate than Method A, since if the method of measuring the displaced volume is accurate, the effect of variation of density along the length of the bolt of wood is eliminated.

The discussion of the other variables noted under Method A also applies. For rough wood, Method A is quicker since it is not necessary to bark the whole cord.

DETERMINATION OF RACKED AND SCALED VOLUME RATIOS

The previous determinations deal with the ideally racked cord, which usually is not identical in volume with commercially scaled wood. This difference is caused by:

(1) Voids along the sides and bottom of the laboratory cord as racked, which usually are filled in the ordinary scaled cord.
(2) Shaking or jolting during shipment (if the scaling is done at the unloading terminal), which causes the wood to settle more compactly.
(3) The "shrink" on sawing and repiling 8-foot wood in 4-foot lengths.

Only the first two factors concern wood purchased in 4-foot lengths; all three apply to wood coming to the mill in 8-foot lengths. Hence a determination of the volume ratio of racked 4-foot and scaled 4-foot cords involves but one step, while that of racked 4-foot and scaled 8-foot cords involves two steps. The first step, applicable to both situations, is a determination of the relative volumes of scaled and racked wood of the same length.

(A) Ratio of 4-Foot Racked (Laboratory) Cord to 4-Foot Scaled Cord

Apparatus. A 4-foot laboratory cord rack as described under Method A above.

Procedure. Unload the car or other unit and stack all its contents, or say every third log unloaded, directly into the rack as described under Method A. If

the last portion of wood left does not fill the rack, carefully level off and estimate the portion of a cord it represents by stretching a string along the ends of the wood so that the voids and protrusions balance along the top. Calculate the equivalent number of cords if the unit were racked.

Calculation. Calculate the volume of the scaled cord in terms of the racked (laboratory) cord from the formula:

$$VS_4 = \frac{NR_4 \times VR_4}{NS_4}$$

where

VS_4 = volume of the 4-foot scaled cord
VR_4 = volume of the 4-foot racked cord
NS_4 = number of cords in the unit shipment as scaled (4-foot lengths)
NR_4 = equivalent number of cords in unit as racked (4-foot lengths)

This determination should be carried out on at least two carloads of a shipment of the same class of wood to minimize scaling variations not under laboratory control. For 4-foot wood the variation of VS_4 from VR_4 will usually be less than 2%.

(B) Ratio of 8-Foot Racked (Laboratory) Cord to 8-Foot Scaled Cord

Apparatus. An 8-foot laboratory cord rack, 8 feet long, with ends 4 feet high and 6 feet wide, constructed and equipped as described under Method A above. It may advantageously consist of the rack for 4-foot wood, to which a parallel section is bolted when needed.

Procedure. Follow the procedure described under (A) for the determination of the ratio between the 4-foot cords, keeping in mind that 1 rackful in this case represents 2 cords, and that the amount of wood in the last partially filled rack must also be estimated on this basis.

Calculations. The formula is:

$$VS_8 = \frac{NR_8 \times VR_8}{NS_8}$$

where

VS_8 = volume of 8-foot scaled cord
VR_8 = volume of 8-foot racked (laboratory) cord
NS_8 = number of cords in shipment as scaled (8-foot lengths)
NR_8 = number of cords in shipment as racked (8-foot lengths)

(C) Ratio of 8-Foot and 4-Foot Racked (Laboratory) Cords

This ratio may be determined by two methods which, to avoid confusion with Methods A and B as described above for determining physical characteristics, are designated as Methods C(1) and C(2).

METHOD C (1)

Apparatus

1. *An 8-foot laboratory cord rack* as described above.
2. *A 4-foot laborotory rack,* as described previously.
3. *A saw* for cutting the 8-foot logs into two 4-foot sections.

Procedure

Rack at least 10 cords (5 rackfuls) of 8-foot size in the laboratory cord rack, as described under (A) for racking the 4-foot wood, putting aside each rackful until the 10 cords have been measured. (Five rackfuls from the determination of the ratio of the 8-foot racked cord to the 8-foot scaled cord above may be laid aside for this determination, taking care that it is not mixed with other wood.)

Saw this wood into 4-foot lengths and rerack in the 4-foot rack, using the method as described for racking. Carefully level off the last partially filled rackful and estimate the fraction of a cord it represents, as before.

Calculations

Use the formula:

$$VR = \frac{NR_{4a} \times VR_4}{NR_{8a}}$$

where

NR_{4a} = number of racked 4-foot cords reracked after sawing
NR_{8a} = number of racked 8-foot cords sawed for reracking
VR_8 and VR_4 have the same meaning as above

METHOD C (2)

Apparatus

1. *An 8-foot laboratory cord rack* as described.
2. *A 4-foot laboratory cord rack* as described.
3. *A scale* of about 3 tons capacity with the 4-foot rack mounted on it. (If this is not available, a scale of about 250 pounds capacity can be used.)

Procedure

Fill the 8-foot rack as described. Empty it and saw each log into two equal sections, discarding one end of each log. Rerack as 4-foot wood and weigh. The rack will not be full, so complete the filling with 4-foot logs (from those discarded) of average size. Finally, weigh the full cord, and adjust the weights for the actual lengths of the logs.

To increase the accuracy, this determination should be repeated and an average taken.

Calculations

Use the formula:

$$VR_8 = \frac{WR_4 \times VR_4}{WR_8}$$

WR_4 = average weight of 4-foot racked cord
WR_8 = average weight of 8-foot racked cord
VR_4 = volume of 4-foot racked cord

Limitations

The determination of the volume ratio of the entire scaled shipment to the racked cord is practicable only when a relatively small unit of wood (for example, a railroad carload) is scaled, unless representative samples from larger lots are taken. The value of the detailed examination of the racked laboratory cord is considerably lessened if this ratio is not known accurately. However, the ratio between 4-foot and 8-foot wood can often be determined, by the procedure given, from any small representative portion of the wood at some intermediate point where the wood is in relatively small units; for example, at the railroad terminal before it is loaded for water shipment, or at a central collection point.

DETERMINATION BY RAILROAD SCALING

If the equipment is available, direct determination of the cord, scaled on a railroad car, can be made. The method is as follows:

Apparatus

1. *An Accurate Railroad-Car Scale.*
2. *A Power-Driven Saw.*
3. *Other apparatus,* exactly as described for Methods A or B above (excepting the racks or the large 3- to 6-ton scales).

Test Specimen

The sample shall consist of not less than 0.5% of the lot of wood nor less than 30 logs and shall be withdrawn at random from cars of wood so as to be representative at the shipment. It is advisable to use larger samples if the wood is obviously nonuniform as to size, dryness, condition, etc., or if more time is available.

Procedure

Record the volume of the wood as scaled by the scaler. Accurately weigh the car of wood. Remove the test specimens as directed. If in 8-foot lengths, saw the specimen sticks at once and proceed as outlined in Method A or B.

Report

The same figures will be recorded as previously, with the scaled or racked volumes. Since the weight per scaled cord is known, the dry wood and volume of wood per scaled cord can be calculated directly.

Accuracy

The accuracy of this method should be the same as that of the other methods. It avoids the determination of the racking ratios. The determinations should be made immediately following the weighing and sampling, whereas in the previous methods a lapse of time need be avoided only after the wood is weighed in the cord rack.

DETERMINATION OF WEIGHT OF UNIT VOLUME OF CHIPS

The density of the wood influences the yield of pulp, and this figure obtained in Methods A and B above is useful in determining the elements of the cost of pulp. A related value, which is somewhat more useful when making a chemical pulp, is the pounds of dry wood per cubic foot of chips. The cubic capacity of a digester will be known, or can be readily measured, and the determination of the weight of chips per unit volume will allow the weight of wood charged to be calculated with a fair degree of accuracy, hence permitting a check on cooking efficiency or a comparison of pulping costs if the pulp is sampled and weighed.

Apparatus

1. *Volume-box* of approximately cubical shape, strongly made and rigid, open on top, and with a volume of at least 4 cubic feet.
2. *Scales* accurate to within $^1/_4$ pound or less and with a capacity of about 100 pounds, or sufficient for the box plus chips.
3. *Drying oven and chip sample trays,* or the apparatus for moisture determinations as described in TAPPI Standard T 3 m.
4. *Chip compressor,* consisting of a circular sheet-iron disk at least $^1/_8$ inch thick and 7.82 inches in diameter.
5. *Weights,* about 7 inches in diameter, which with the chip compressor (item 4), correspond to the weight of chips in a column one third square foot in cross section and one half the height of the digester.

If the chips are obtained from the mill supply, as is most desirable, no other apparatus is required. If these chips are not available, there will also be required:

6. *Laboratory chipper and screens* corresponding in mesh to those used in the mill concerned.
7. *Cut-off saw* for sample logs.

Procedure

Accurately measure the volume-box to determine its exact volume. If made of hygroscopic material, weigh it empty each time it is used. Fill it with representative chips and shake down by jarring slightly three times. Add chips to overflowing and remove the excess with a straightedge. Again weigh the box and chips and determine the net weight of chips. Place the round chip compressor (without weights) on the chips approximately at the center of the top surface of the chip mass. Then add the weights corresponding to approximately the pressure of chips one half the digester height. Measure the distance which the bottom face of the compressor is submerged below the level of the box sides.

Mix the chips and quarter them down to a sample of not less than 1 pound. Determine the moisture on this sample.

Report

Calculate the volume of the chips as the inside volume of the box, minus the product of the horizontal cross section of the box interior and the depression of the weight holder below the top of the box. Report the weight of wood per cubic foot of chips (a) as received and (b) moisture-free:

$$(a) = \frac{\text{wt. of chips as received (in pounds)}}{\text{corrected box volume (in cubic feet)}}$$

$$(b) = \frac{\text{wt. of moisture-free chips}}{\text{corrected box volume}}$$

Notes: 1. It is advisable to use as large a volume-box as can be conveniently handled so as to reduce the boundary errors. At the sides, bottom, and top of the box there will be voids, similar to the voids when logs are piled in a one-cord rack, which do not exist to the same extent when a large body of chips is piled. For a cubical box of 4 cubic feet the ratio of surface voids to total volume is one half as great as with a 1-cubic foot box.

2. The weight of wood per cubic foot of chips as determined in a small box without compression will not represent the density of chips in a digester, since in all parts but the top layer in the digester the chips are compressed by the weight of those above. Many sulphite digesters are about 40 feet high; hence in measurement the chips should be subjected to a pressure equivalent to the average pressure in such a digester, i.e., the weight of a 20-foot column of chips. The compression will not be directly proportional to the weight applied.

3. It is not believed that any useful purpose would be served by specifying a nonvariant chip length, screen sizes, measuring-box size, or compression pressure. The purpose

of this method is not to determine an absolute property of the wood but to determine a property as influenced by the particular chip length, screen sizes, and digester height in a particular mill.

ADDITIONAL INFORMATION

Commercial Evaluation

In order to have a practical value, the figures of physical characteristics should be so combined as to give the mill executive a direct means of using them. Following is a suggested example:

First establish a unit of quantity. As convenient as any other is 1000 pounds (moisture-free basis) of screened chips. A unit of quantity of 1 ton of air-dry pulp would be most advantageous from the mill standpoint, but then operating and chemical variables would enter.

Assuming a unit of quantity based on moisture-free screened chips, the following general equation can be evolved:

$$a\ (P + bF + K) = C$$

Where C = the cost per unit quantity (1000 pounds of moisture-free screened chips)
P = the producer's price per cord (or the f.o.b. price)
F = the freight rate per 100 pounds (or bF is the freight rate per cord)
K = the wood-room and handling cost per cord of the type of pulpwood under consideration
a and b = constants dependent upon the physical characteristics of the wood

The numerical values of the constants a and b are derived for each class of pulpwoods as follows: Constant a represents the number of scaled cords necessary for the production of the unit of quantity, in this case 1000 pounds of chips, and is therefore dependent upon (1) the number of pounds of moisture-free wood in a cord as determined by the laboratory, and (2) the losses, if any, which occur in the mill practice of handling, barking, chipping, screening, etc. These losses are almost negligible on barked wood without large knots, which requires little preparation before chipping Rough wood, on the other hand, may lose as much as 25% of the wood substance on barking. This value is dependent as much on the barking equipment as on the wood itself, and must be determined individually for each mill.

Assuming that the losses have been determined, if we let

WC = pounds of moisture-free screened chips per cord
WW = total weight of moisture-free wood per cord
PL = percentage lost in handling

then

$$WC = WW - (WW \times PL)$$

and

$$a = \frac{1000}{WD}$$

The value for b depends on the gross weight of the cord (as received) and since F is expressed as a rate per hundred pounds, b is then equal to the gross (original) weight of the scaled cord divided by 100.

The responsibility for the determination of the fixed wood-room charges K lies primarily with the accounting departments. These, however, may be over-all figures, and in order to be adequate for this calculation they must be broken down as far as possible into units which will permit the assignment of comparative costs to the different classes of wood which are handled; or experiments as to the amount of wood, man-hours, power, etc., may be necessary. The chief distinction is between the cost of handling rough and peeled wood. The various items which must be considered are somewhat as follows: labor, direct and indirect; repair charges; administration; depreciation; taxes and insurance; power; yard handling, including scaling cost, yard storage, etc.; and the fuel value of credit of the bark, knots, and chipper refuse. These figures will differ for each mill, as they depend entirely upon the peculiarities of operation of each individual wood room.

The numerical value of K is then the net wood-room cost per cord which is directly chargeable to any type of pulpwood. Applying the determined values of a, b, and K to the general equation

$$a\ (P + bF + K) = C$$

P and C are the two independent variables and their relation is expressed by a straight line. The freight rate F is a constant value for wood from each locality. If it is a given rate per pound, then bF is a constant. If it is an agreement figure per cord, the gross weight has no influence on its value and b can be ommitted; and if the wood is delivered in the price agreement, the item bF becomes zero.

Curves or charts are not usually as acceptable for

Table I.[a] **Cost of Popular 8-foot + 4.41% Peeled Old**

Equations: $0.478\ (P + 25.03\ F + 0.826) = C$.
$0.478\ (DP + 0.826) = C$.
P = Producer's price in dollars per cord.
F = Freight rate in dollars per hundred pounds.
DP = Delivered price in dollars per cord.
C = Cost per 1000 pounds of moisture-free ungraded chips.

DP	*C*	*DP*	*C*	*DP*	*C*	*DP*	*C*	*DP*	*C*
5.00	2.79	9.00	4.70	13.00	6.61	17.00	8.52	21.00	10.43
.10	2.83	.10	4.74	.10	6.60	.10	8.57	.10	10.48
.20	2.88	.20	4.79	.20	6.70	.20	8.62	.20	10.53
.30	2.93	.30	4.84	.30	6.75	.30	8.66	.30	10.58
.40	2.98	.40	4.89	.40	6.80	.40	8.71	.40	10.62
5.50	3.02	9.50	4.94	13.50	6.85	17.50	8.76	21.50	10.67
.60	3.07	.60	4.98	.60	6.90	.60	8.81	.60	10.72
.70	3.12	.70	5.03	.70	6.94	.70	8.86	.70	10.77
.80	3.17	.80	5.08	.80	6.99	.80	8.90	.80	10.82
.90	3.22	.90	5.13	.90	7.04	.90	8.95	.90	10.86
6.00	3.26	10.00	5.18	14.00	7.09	18.00	9.00	22.00	10.91
.10	3.31	.10	5.22	.10	7.13	.10	9.05	.10	10.96
.20	3.36	.20	5.27	.20	7.18	.20	9.09	.20	11.01
.30	3.41	.30	5.32	.30	7.23	.30	9.14	.30	11.05
.40	3.45	.40	5.37	.40	7.28	.40	9.19	.40	11.10
6.50	3.50	10.50	5.41	14.50	7.33	18.50	9.24	22.50	11.15
.60	3.55	.60	5.46	.60	7.37	.60	9.29	.60	11.20
.70	3.60	.70	5.51	.70	7.42	.70	9.33	.70	11.25
.80	3.65	.80	5.56	.80	7.47	.80	9.38	.80	11.29
.90	3.69	.90	5.61	.90	7.52	.90	9.43	.90	11.34
7.00	3.74	11.00	5.65	15.00	7.57	19.00	9.48	23.00	11.39
.10	3.79	.10	5.70	.10	7.61	.10	9.52	.10	11.44
.20	3.84	.20	5.75	.20	7.66	.20	9.57	.20	11.48
.30	3.88	.30	5.80	.30	7.71	.30	9.62	.30	11.53
.40	3.93	.40	5.84	.40	7.76	.40	9.67	.40	11.58
7.50	3.98	11.50	5.89	15.50	7.80	19.50	9.72	23.50	11.63
.60	4.03	.60	5.94	.60	7.85	.60	9.76	.60	11.68
.70	4.08	.70	5.99	.70	7.90	.70	9.81	.70	11.72
.80	4.12	.80	6.04	.80	7.95	.80	9.86	.80	11.77
.90	4.17	.90	6.08	.90	8.00	.90	9.91	.90	11.82
8.00	4.22	12.00	6.13	16.00	8.04	20.00	9.96	24.00	11.87
.10	4.27	.10	6.18	.10	8.09	.10	10.00	.10	11.91
.20	4.31	.20	6.23	.20	8.14	.20	10.05	.20	11.96
.30	4.36	.30	6.27	.30	8.19	.30	10.10	.30	12.01
.40	4.41	.40	6.32	.40	8.23	.40	10.15	.40	12.06
8.50	4.46	12.50	6.37	16.50	8.28	20.50	10.19	24.50	12.11
.60	4.51	.60	6.42	.60	8.33	.60	10.24	.60	12.15
.70	4.55	.70	6.47	.70	8.38	.70	10.29	.70	12.20
.80	4.60	.80	6.51	.80	8.43	.80	10.34	.80	12.25
.90	4.65	.90	6.56	.90	8.47	.90	10.39	.90	12.29
9.00	4.70	13.00	6.61	17.00	8.52	21.00	10.43	25.00	12.35

[a] The first equation gives the values when the f.o.b. or producer's price is available, to which a freight cost is added. The second equation is for use when the wood cost is on a delivered basis. The constants in the parenthesis represent the wood-room cost per cord for the particular wood; the constant outside the parentheses is the fraction of a cord necessary to produce 1000 pounds of moisture-free chips under the given conditions.

nontechnical use as are tables. A table can be easily prepared for each wood which will provide ample room for a brief description of the wood (type of wood, length, per cent of excess length, green or dry, barked or rough, etc.) and for a table giving the values for C for 10-cent increments over a $20 range in the prices of pulpwood P. An example of this is given in Table I.

Loose-leaf sheets provided with the proper index, permit a continuation of work with the addition of fiber distinctions in classes of pulpwoods as the data become more complete. Such tables provide a permanent, convenient, and increasingly accurate and valuable aid to those in charge of the purchase of pulpwood.

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LETTERS TO THE EDITOR

Preservation of Groundwood Pulp

Ed. Note: The following is a discussion of the article "Preservation of Groundwood Pulp During Storage," by B. F. Shema (*Tappi*, 32, No. 5, June 1949, pp. 227–228) by Henry D. Fischer, paper consultant, Westcott & Mapes, Inc., Architects and Engineers, New Haven, Conn.

Readers of *Tappi* are urged to present similar discussions of any articles published in *Tappi*.

A casual reading of Dr. Shema's paper gives an impression that the organic mercury compounds do not afford the protection to groundwood pulp against deterioration in storage that can be obtained by the use of the chlorinated phenols.

The writer a few years ago conducted a series of tests which resulted in a different conclusion.

The firm with which the writer was connected at that time owned a small groundwood mill operated solely by water power. The water shed of the river is rather small and has little storage so that the grinding season is comparatively short, October 15 to May 15 being about the usual expectation. Economical transportation was by water, all of which conditions resulted in rather extended periods of storage for the groundwood, usually through the summer, and more or less discoloration of the pulp before it could be consumed. The usual form of discoloration was a light, more or less uniformly distributed grayness, called in mill parlance, "mildew." While not microscopically identified, it is believed to be similar to "blue stain" infection of lumber, possibly a member of the genus *Mucor*.

More occasional infections were a species identified as *Cladisporum Herbarum* which caused small, hard brownish grains like cracked wheat, and Penicillium and Acrostalagmus, which cause reddish brown patches.

Two independent series of tests were made in the spring near the close of the grinding season of the years 1937 and 1938, regular mill practice being followed except for the application of the preservative. The pulp as shipped tested about 53% air-dry.

The arrangement for applying the chemical was quite similar to that adopted by Dr. Shema, that is, a perforated pipe was located just back of the press roll on the wet machine and the solution allowed to dribble from it on to the pulp as it came in to wind up to form the lap. The dispersion of the solution under the press roll and the further solution circulation during the dewatering of the pulp by compression of the laps in the hydraulic press was expected to be adequate to reach all portions of the pulp. The flow of the solution was timed and mixtures made of the desired concentration to provide the proportion of chemical to pulp decided upon.

The first series of tests was made in May, 1937. Two samples of about one ton each of air-dried pulp were treated, one with two pounds and one with four pounds of Dowicide H (sodium tetrachlorphenate) per air-dry ton. This treated pulp was stored in the regular way at the pulp mill during the summer and shipped by vessel in the first fall cargo.

When received at the paperboard mill, the sample bales, together with an equal number of untreated bales as a control, were stored in a warm damp basement with little air circulation in order to provide the most severe test conditions.

One bale from each test run and one control bale were opened weekly, beginning November 20, 1937. Through November and December there was only a slight difference in appearance in the favor of the treated pulp. About the middle of January, the difference became more noticeable, the treated pulp remaining comparatively bright. Individual bales varied somewhat but by the time the last of the samples were reached, toward the end of March, 1938, the untreated control pulp showed considerable "mildew" and some brown fungus spots while the treated samples were free of mildew and of comparatively good color. No great difference was observable in the two treated samples. None of the hard lumps, attributed to *Cladisporum Herbarum* appeared in either treated pulp or the controls.

The treated pulp bales after opening had been accumulated and were used in a test run on the paperboard machine. The pulp worked satisfactorily but the evolution of phenol was so great as to rule out the use of this preservative material. Other more suitable preservative materials were therefore investigated.

Among the materials suggested, were Permatox (technical pentachlorphenate) and the two Lignasan compounds used by Dr. Shema, that is, ethyl mercuric chloride and ethyl mercuric phosphate. It was thought that the phosphate might be somewhat less volatile and longer lasting in its effects than the chloride.

Pulp samples of about twenty bales each treated with these materials in the following amounts were prepared about June 1, 1938, the bales being of the standard 224-lb. net weight.

Sample symbol	*Material used for treatment*	*Amount of chemical per air-dry ton,-lb.*
A	Permatox	3
B	Lignasan (chloride)	1/2
C	Lignasan (chloride)	1/8
D	Lignasan (phosphate)	1/2
E	Lignasan (phosphate)	1/8

These were shipped as part of a vessel cargo arriving at the paperboard mill on August 11, 1938 and, with a corresponding amount of untreated pulp from the same batch as a control, were stored as previously described for the first test.

Starting, September 29, 1938, one bale from each test lot was opened at intervals of one to two weeks. At this time, the control showed a little mildew and rather poor color; the Permatox a little mildew but good color; and the Lignasan samples narrow wavy lines of mildew similar

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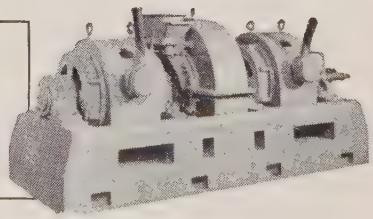

to the mark left by the edge of a liquid soaking into paper. The color in general, however, was equal to fresh pulp. The appearance of these lines of mildew was such as to suggest that the solution had spread through the laps pretty generally.

From week to week the appearance of the individual bales varied somewhat, particularly in the control and the Permatox treated pulp but in general there was a steady increase in mildew and a deterioration in color, the pulp turning brown. On the other hand, the Lignasan treated samples showed only the faint narrow lines of mildew previously described and retained a color almost equal to freshly ground pulp.

On January 9, 1939, it was necessary to move the remainder of the samples to another part of the cellar which was somewhat cooler and dryer. At this time the control and Permatox treated pulp began to show a number of brown and black fungus spots as well as mildew and a general brown color of the pulp. Pulp in this condition would not be useable in better grades of board. The Lignasan pulp in general preserved an excellent color but showed some mildew and small fungus spots near the edges, perhaps from reinfection. All the pulp bales had dried out to a noticeable extent.

The tendencies described above continued and, while the weekly records are available, to save space only the quarterly yearly conditions will be noted here. On March 29, 1939, two control bales showed (1) "color poor, brown tint, much mildew, several large patches, brown stain showing all through lap," (2) "color fair, somewhat brown, considerable mildew, not much fungus."

Permatox "Color fair, considerable mildew, not much fungus."
Lignasan—Sample B "Color and appearance perfect, same as fresh pulp, no mildew or fungus."
Sample C "Color excellent, very little mildew and that in patches, one spot brown fungus similar to that which caused hard brown lumps."
Sample D "Color excellent, almost no mildew, one brown fungus infection spot."
Sample E "Color very good and bright except at edge where wet by water from outside a little patchy mildew."

The last samples examined June 21, 1939 were reported on as follows:

Control Supply exhausted—no report.
Permatox "Color fair, slightly brown, no mildew, some black spots and several large brown fungus patches."
Lagnasan—Sample B "Color very good and bright, very little mildew, no fungus except a little infection from edges."
Sample C "Color perfect, a little shading of mildew in places, no fungus."
Sample D "Color perfect, very little mildew, in a few narrow streaks, no fungus except a little red color at edge."
Sample E "Color good except where saturated by drip, these parts infected with fungus and mildew."

In general, it may be said that the pulp in the control samples was in poor condition early in the test and that treated with Permatox was not useable in better grades of paper after about six months. The Lignasan treated pulp, except where reinfected, preserved an excellent color for the full duration of the test. No consistent difference could be observed between the effect of the two Lignasan compounds nor of the larger or smaller quantities.

About the time these tests were completed demand for pulp had increased to a point where it was being used faster than it could be made and no preservative treatment for storage was required. Present demand conditions, however, are reverting to those at the time the tests were begun and it is believed that these results may be of interest to firms compelled to store wet lapped pulp, whether of the groundwood or chemical variety.

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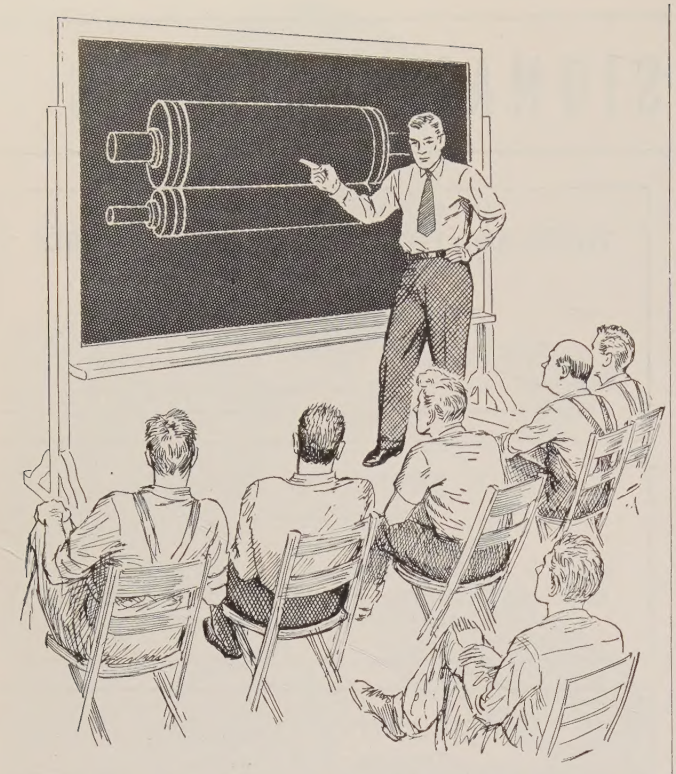

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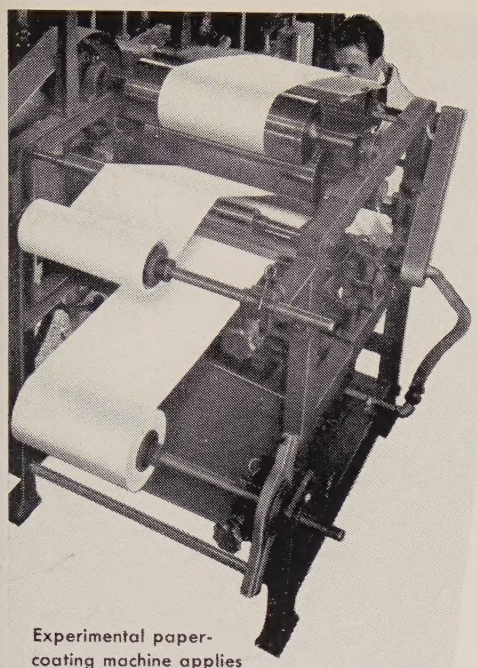

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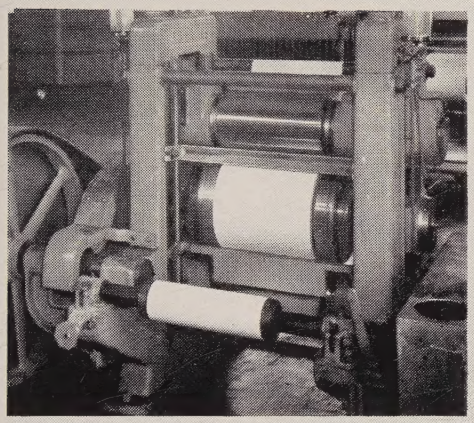

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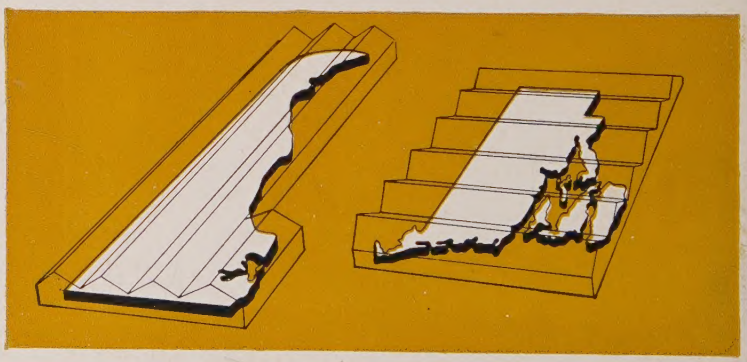

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